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CHANGES IN ACID PHOSPHATASE ACTIVITY IN *SPODOPTERA LITURA* (LEPIDOPTERA-NOCTUIDAE) DURING THE POST-EMBRYONIC AND ADULT DEVELOPMENT

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(*Received 30 June 1984*)

The activity of the lysosomal marker enzyme acid phosphatase has been studied in the whole body homogenate, fat body and testis during various stages of development. The total enzyme activity in the whole body homogenate increased gradually from the second instar larva to the late prepupal stage, it remained more or less the same in the freshly moulted pupa but declined during the first half of the pupal duration. The activity in the three day old pupa remained only one third of the late prepupal value. However, a further increase in the activity could be noticed in the eight days old pupa. The enzyme activity in the fat body also increased gradually from the early fifth instar larva to the late fifth instar larva. The activity increased significantly from the late fifth instar to the non-feeding stage and remained high in freshly moulted pupa. The testis showed a low level of acid phosphatase activity up to the non-feeding stage and this increased gradually up to the mid pupal stage, followed by a steady and significant increase during the late pupal and adult stages, reaching a peak value in five day old males.

(*Key words:* acid phosphatase, whole body, fat body, testis)

INTRODUCTION

The tobacco caterpillar *Spodoptera litura* (Lepidoptera-Noctuidae) is a holometabolous insect, wherein important and far-reaching changes occur during metamorphosis. Most of the organs functioning during the larval life are destroyed in the early pupal stage (histolytic phase) which is followed by the formation of adult organs during the late pupal stage (histogenic phase). During histolysis of larval organs cellular destruction is mediated, among others, by lysosomal activity (LOCKSHIN, 1969; VERKUIL, 1979).

For the present study acid phosphatase has been selected because of its importance in biological processes such as development, growth, maturation and histolysis which need high levels of energy. Moreover acid phosphatase is often used as a marker enzyme for lysosomal activity in insects (LOCKE & SYKES, 1975; VERKUIL, 1979).

To date several EM cytochemical studies are available on acid phosphatase activity. Nevertheless, quantitative investigations of the changes of acid phosphatase levels during post-embryonic development are few in the case of Lepidoptera (SRIDHARA & BHAT, 1963; GILBERT & HUDDLESTON, 1965), although there are some studies relating to the Dipteran species (HEGDAKER & SMALLMAN, 1967; PRICE, 1974; VERKUIL, 1979; DELOACH & MAYER, 1979; DELOACH *et al.*, 1981).

In the present study an attempt has been made to investigate the course

of acid phosphatase activity during the various stages of post-embryonic development in the whole body, fat body and testis homogenates.

MATERIALS AND METHODS

The insects were reared in the laboratory at 27 ± 1°C temperature, 70 ± 5% RH and 14:10 LD period on an artificial diet (NAGARKATTI & PRAKESH, 1974). For the present study the following stages of insects were used: early second instar, late second instar, early third instar, late third instar, early fourth instar, late fourth instar, early fifth instar, mid fifth instar, late fifth instar, non-feeding stage, early prepupa, late prepupa, pupa 0 hr, pupa 1 day, pupa 3 days, pupa 8 days, freshly emerged male, old unmated male and old mated male.

The insects from various stages were dissected out in cold glass distilled water and the gut contents were removed. A 1% homogenate of the whole body was then prepared in cold 1% Triton-X 100 and this was used for the assay of the enzyme. Fat body and testes of various stages were dissected out in cold glass distilled water, cleared from the surrounding tissue and a 1% homogenate of them was prepared in 1% Triton-X 100.

The enzyme was assayed according to the method of HENRICKSON aed CLEVER (1972). The incubation medium consisted of 0.5 ml of substrate (*p* nitrophenyl phosphate disodium), 1.1 ml of 0.2 M sodium acetate buffer (pH 5.5) and 0.2 ml of the homogenate. The substrate concentrations used were 6 μ mols for the whole body homogenate, 4 μ mols for the fat body and 6 μ mols for the testis homogenates. Enzyme samples with buffer were incubated for 10 min at 37°C to exclude glucose-6-phosphatase activity as suggested by BEAUFAY *et al.* (1954). After incubation with the substrate for 1 hour at 37°C, the reaction was terminated by the addition of 4.5 ml of 0.1 N sodium hydroxide. The colour developed was read at 420 nm against an enzyme blank. The amount of *p*-nitrophenol released as a result of the enzyme activity was determined from a standard curve drawn, using standard *p*-nitrophenol (10 μ mols/ml). The protein content was estimated by the method of LOWRY *et al.* (1951) using Bovine serum albumin fraction V as standard.

RESULTS

The total and specific activities of acid phosphatase in the whole body homogenate at various stages of development are shown in Table 1. Initially the total activity of this enzyme was found to be low in the early second instar larvae but increased slightly in the late second instar. The newly moulted third instar larvae showed a decline in its activity. However, it increased further in the late third instar and remained more or less the same in the early and late fourth instar larvae. Thereafter, the activity declined slightly in the early fifth instar larvae, but it increased steadily during the rest of the larval duration and reached its peak value in the late prepupae. During early pupal development the total activity decreased gradually and it remained only at one-third of the prepupal activity. The activity however shot up to a significant level (92%) in eight day old pupae. The specific activity of the enzyme exhibited more or less the same pattern from the early second instar larvae to the freshly moulted pupal stage but it declined during the early pupal devolopment (three days) and again increased markedly in eight day old pupae.

Table 2 shows the changes in the total and specific activities of the enzyme acid phosphatase in the fat body. In actively feeding early fifth instar larvae the total activity of the enzyme was found to be low and it increased gradually during the mid and late stages of larval development. There was a significant increase in the total activity from the late fifth instar stage to the

TABLE 1. Changes in the pattern of acid phosphatase activity in the whole body homogenates of *Spodoptera litura* during the post-embryonic development.

Stages		μ moles of PNP released/h	
		per g tissue	per mg protein
Early 2nd instar	(3)	88.66 ± 6.06	2.70 ± 0.20
Late 2nd instar	(3)	116.32 ± 4.35	3.06 ± 0.13
Early 3rd instar	(3)	104.31 ± 8.08	3.12 ± 0.15
Late 3rd instar	(4)	141.75 ± 8.94	3.14 ± 0.36
Early 4th instar	(5)	122.18 ± 11.13	2.62 ± 0.37
Late 4th instar	(6)	116.50 ± 6.29	3.28 ± 0.17
Early 5th instar	(8)	93.94 ± 7.62	2.61 ± 0.22
Mid 5th instar	(8)	124.84 ± 12.72	3.13 ± 0.45
Late 5th instar	(7)	143.03 ± 15.08	3.12 ± 0.27
Non feeding stage	(7)	169.95 ± 17.17	3.34 ± 0.36
Early prepupa	(8)	180.00 ± 10.69	3.07 ± 0.36
Late prepupa	(5)	203.32 ± 21.38	3.00 ± 0.26
Pupa 0hr old	(7)	192.85 ± 26.78	3.12 ± 0.40
Pupa 1 day old	(6)	152.54 ± 32.76	2.20 ± 0.30
Pupa 3 day old	(6)	81.60 ± 12.94	1.72 ± 0.40
Pupa 8 day old	(6)	156.94 ± 17.19	2.65 ± 0.32

The values represent means ± S D of the number of determinations given in parenthesis 5–6 insects were used from early 2nd instar, to late 4th instar and 3–4 insects were used for rest of the stages for each determination.

TABLE 2. Changes in the activity of acid phosphatase in the fat body during the various stages of development.

Stage		μ mols PNP released/h	
		per g tissue	per mg protein
Early 5th instar	(5)	15.89 ± 3.23	0.78 ± 0.07
Mid 5th instar	(6)	27.62 ± 4.34	1.14 ± 0.06
Late 5th instar	(7)	58.79 ± 5.78	0.82 ± 0.07
Non-feeding stage	(6)	144.83 ± 22.38	1.89 ± 0.21
Early prepupa	(4)	159.30 ± 7.90	2.23 ± 0.23
Late prepupa	(5)	134.92 ± 17.97	1.28 ± 0.09
Pupa 0 day old	(4)	167.22 ± 23.77	1.64 ± 0.16

The values represent means ± S D of the number of values given in parenthesis. For aech determination, tissue from 3–5 insects were pooled together.

non-feeding stage, which remained more or less constant in the early and late prepupae and freshly moulted pupae. The specific activity of the enzyme was also found to be low in the early fifth instar, and it increased in the mid fifth instar, but declined in the late fifth instar insects. A gradual increase was noticed from the late fifth instar up to the early prepupae, but declined again in the late prepupae and remained at the same level in freshly moulted pupae.

The testis of the early fifth instar larvae showed low total activity of acid phosphatase which increased gradually and reached a peak value in old males (Table 3). The specific activity was also low in early stages but with the advancement of age it increased gradually. Highest specific activity was found in old males where the values were nearly five-fold more as compared with early fifth instar larvae (Table 3).

DISCUSSION

Although acid phosphatase activity increased in the whole body homogenate just before every moult, this increase was more pronounced in the final instar of *Spodoptera litura*. During the non-feeding and prepupal stages the enzyme activity increased markedly and its highest level was found in the late prepupae and remained high in freshly moulted pupae, wherein larval organs presumably begin to undergo histolysis. These results are in agreement with the studies of SRIDHARA & BHAT (1963) on the whole body homogenate of *Bombyx mori*. It decreased markedly in three day old pupae, but increased again during the last few days of pupal period, when differentiation of imaginal

TABLE 3. Changes in the pattern of acid phosphatase activity in the testis of *Spodoptera litura* during larval, pupal and adult stadia.

Stage		μ mols PNP released/h	
		per g tissue	per mg protein
Early 5th instar	(6)	131.4 ± 16	2.2 ± 0.13
Mid 5th instar	(6)	119.9 ± 13	1.7 ± 0.09
Non-feeding stage	(4)	150.1 ± 23	1.9 ± 0.16
Late prepupa	(5)	213.3 ± 22	2.6 ± 0.16
Pupa 1 day old	(7)	246.9 ± 31	3.2 ± 0.29
Pupa 3 day old	(5)	271.1 ± 37	3.8 ± 0.37
Pupa 8 day old	(5)	486.3 ± 51	4.9 ± 0.42
Freshly emerged male	(6)	699.5 ± 94	6.9 ± 0.47
Old unmated male	(5)	1089.4 ± 217	10.1 ± 0.93
Old mated male	(7)	1152.1 ± 176	11.9 ± 1. 4

The values represent means ± S D of the number of values given in parenthesis. For each determination tissue from 3–5 insects were pooled together.

structures should be taking place (MATHAI & NAIR, 1982). In *Stomoxys calcitrans* a three-fold increase in acid phosphatase activity was noticed during the pupal development and this was associated with the disintegration of larval tissues (DELOACH & MAYER, 1979). However, one should not ignore the fact that the use of whole body homogenate has its limitations. One of them is that, changes occurring in one tissue may not be taking place in another tissue and the actual changes in the activity might be masked by the presence of other tissues in the homogenate.

In the present insect the enzyme activity in the fat body increased markedly during the non-feeding and early prepupal stages and it remained high during the late prepupal and early pupal stages (VERKUIL, 1979). The rise in acid phosphatase activity at the late stage of larval development observed here in *Spodoptera* is presumably due to increased moulting hormone titre, leading to autophagic and heterophagic processes. In a number of insect species and several insect tissues there is convincing experimental evidence to show that ecdysteroids induce acid phosphatase activity (RADFORD & MISCH, 1971; AIZENZON *et al*, 1975; SASS & KOVACS, 1975, 1977; SEDLACK & GILBERT, 1976; DEAN, 1978; VERKUIL, 1979; DELOACH *et al.*, 1981).

Numerous radio-immunoassay studies on lepidopterous insects showed that the amount of ecdysteroids in the haemolymph and in the whole body increased in final instar larvae from their wandering stage onwards and reached its peak value during the spinning stage (BOLLENBACHER *et al.*, 1975, 1978; HSIAO & HSIAO, 1977; LAFONT *et al.*, 1977; MAROY & TARNOY, 1978; DEAN *et al.*, 1980). Hence it is reasonable to conclude that in the present species also ecdysteroids might be responsible for the induction of acid phosphatase after the cessation of feeding. The high acid phosphatase activity observed in freshly moulted pupae was probably due to the presence of high ecdysteroid titre as reported for Galleria (SEHNAL *et al.*, 1981) and this increased activity apparently promotes the onset of pupal-adult transformation.

Acid phosphatase activity has been detected in the testis of several unrelated animals and it is therefore not surprising that this enzyme is well represented in the gonadal tissue, as it has high energy requirements especially during its development and differentiation (BLUM, 1970). The enzyme activity in the testis of *Spodoptera* increased steadily during late larval, pupal and adult stages of its life cycle. The results reported here are at variance with those reported by GILBERT and HUDDLESTON (1965) for the giant silkmoth *Samia cynthia,* in which these workers have observed highest activity during early pupal stage. The testis of *Phormia regina* shows strong acid phosphatase activity during the third instar (STAY, 1959). The testis undergoes histological differentiation in the early stages of the insect development and passes through phases of cell proliferation and cell specialisation. It should therefore be expected to exhibit different patterns of lysosomal activity. In the present study, however, the highest activity is seen in old males, where the ecdysone titre is probably very low or is totally absent. In adult males of *Galleria mellonella* and *Hyalophora cecropia* ecdysone was undetectable (HSIAO & HSIAO, 1977; MCDANIEL, 1970).

However, SHAAYA & KARLSON (1965) observed ecdysone in newly emerged males. Hence it would seem that the acid phosphatase activity in the adult testis may not be regulated by ecdysteroids in *Spodoptera litura.*

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LIFE TABLES AND INTRINSIC RATE OF NATURAL INCREASE OF *COTESIA ORIENTALIS* CHALIKWAR *ET AL.** (HYMENOPTERA, BRACONIDAE), POPULATION ON *EXELASTIS ATOMOSA* FAB.

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Studies on *Cotesia orientalis* Chalikwar *et al.*, (Hymenoptera : Braconidae), larval parasitoid of *Exelastis atomosa* Fab. (Lepidoptera : Pterophoridae) were carried out at laboratory conditions (24 ± 1°C, 55—60%, RH). The mated female had an average 8.4 days ovipositional period and produced an average 91.1 adults with sex ratio 1.289:1 (m : f). The maximum mean progeny production per day 'm_x' was 11.7. The intrinsic rate of increase was 0.188 per female per day and population multiplied to 41.93 times in mean generation time of 19.87 days.

(*Key words:* life tables, intrinsic rate of increase, *Cotesia orientalis*, Chalikwar *et al.*)

INTRODUCTION

In pest managements essential objects are the estimation of rate of growth of pests and their natural enemies (HOWE, 1953). *Cotesia* Cameron is one of the largest genera comprising about 1500 to 2000 species and most of which are parasitoids of the larvae of Macrolepidoptera. *C. orientalis* is a larval parasitoid of *E. atomosa*. The effectiveness of hymenopterous species in terms of their intrinsic rates of natural increase have been assessed by WATSON (1964), CHUNDURWAR, (1975, 1977), BASARKAR & NIKAM (1981) and NIKAM & SATHE (1982). The present findings suggest the population model of *C. orientalis*, a tool for evalution of this parasitoid in biological control.

* New species described, *Oriental Ins.*, in press.

MATERIAL AND METHODS

Newly emerged adults of *C. orientalis* were subjected to 3—4 day old 40 larvae of *E. atomosa* in the rearing cages at laboratory conditions (24 ± 1°C 55–60% RH). Every day different lots of hosts were provided to the parasitoids till their death. The hosts and parasitoids were fed with pigeonpea pods and 20% honey. Fecundity was determined by progeny production.

The life tables were constructed with the help of fecundity and later the intrinsic rates of increase of population of parasitoids were calculated using BIRCH's (1948) formula as elaborated by WATSON (1964)

$$e^{-r\,x}\, m\, l_x m_x = 1$$

where 'e' is the base of natural logarithms, 'x' is the age of the individuals in days, 'l_x' is the number of individuals alive at age 'x' in proportion of one and 'm_x' is the number of female offspring produced per female in the age interval 'x' while 'R_o' is the sum of the products of '$l_x m_x$', the rate of multiplication of population for each generation measured as the female offspring produced.

The approximate value of cohort generation time 'T_c' was calculated as follows:

$$T_c = \frac{l_x m_x x}{l_x m_x}$$

The arbitrary value of innate capacity for increase 'r_c' was calculated from the formula:

$$r_c = \frac{\log R_o}{T_c}$$

This was an arbitrary value for 'r_m' and value of 'r_m up to two decimal places was substituted in the formula until the two values of the equation were found immediately above or below 1096.6.

The two values of $\sum e^{-r_m x} l_x m_x = 1$ were plotted on the horizontal axis against their respective arbitrary 'r_m's on the vertical axis. The two points were joined to give a line which interesected a vertical line drawn from the desired value of $e^{-r_m x} l_x m_x$ (1096.6). The point of intersection gave the value of 'r_m' accurate to three decimal places. The precise generation time 'T' was then calculated from the formula:

$$T = \frac{\log R_o}{r_m}$$

The fenite rate of increase (λ) was calculated as $= e^{-r} m$.

RESULTS AND DISCUSSION

The longevity of ovipositing females averaged 8.4 (range 7—9) days, the number of progeny production averaged 96.1 (range 85 to 105). The male : female offspring averaged 1.289 : 1 (range 1.195 : 1 to 1.390 :1). The first adult mortality was on the 7th day. Average duration of immature stages of parasitoids was 17 days. The maximum mean progeny production stopped on 8th day. In a single generation, the intrinsic rate of increase per female per day was 0.188 (Fig. 1) and population multiplied 41.93 times in generation time 'T' of 19.87 days.

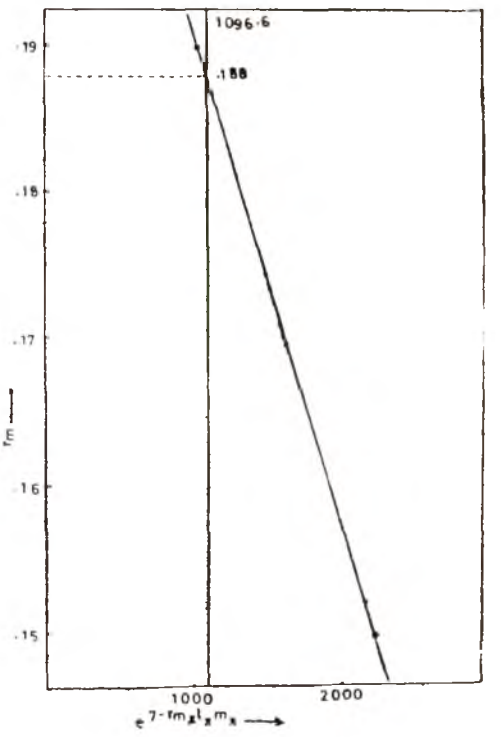

Fig. 1. Determination of intrinsic rate of increase in *C. orientalis*.

$$T_c = \frac{l_x m_x x}{l_x m_x} = \frac{840.77}{41.93} = 20.051$$

where 'T_c' is arbitrary 't'

$$\frac{\log R_o}{T_c} = \frac{\text{Log } 41.93}{20.05} = 0.186$$

where 'R_o' is arbitrary 'r_m'

$T_c = 20.05$, $r_c = 0.186$

Now arbitrary 'r_m's (r_c) are 0.19 and 0.15 $r_m = 0.188$ (Fig. 1) where λ is finite rate of natural increase.

$$T = \log \frac{41.93}{0.188} = 19.87 \text{ days}$$

$T = 19.87$ days.

CHUNDURWAR (1975, 1977) worked the fecundity, life tables and intrinsic rates of natural increase of two hymenopterous parasitoids of *Pthorimaea operculella* (Zeller), *viz.*, *Eriborus trochan-*

teratus (Morley) and *Agathis unicolorata* (Shnef), wherein intrinsic rates of increase were 0.160 and 0.144, the population multiplied to 30.56 and 34.56 times in mean generation time of 19.10 and 24.60 days respectively. In *C. orientalis* intrinsic rate of increase was 0.188 and population multiplied to 41.94 times in generation time 'T' of 19.87 days. In *Xanthopimpla stemmator* (Thun.) 'r_m' was 0.131 and population multiplied to 43.43 times in mean generation time of 28.78 days (BASARKAR & NIKAM 1981). NIKAM & SATHE (1982) in *Cotesia flavipes* (Cameron) observed 0.176 the intake capacity increase per female per day and population multiplied to 30.72 times in mean generation time of 19.45 days.

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THE ASSESSMENT OF LARVICIDAL IMPACT ON MALARIA AND MALARIA VECTOR *ANOPHELES CULICIFACIES* (DIPTERA : CULICIDAE) IN GURGAON URBAN

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Baytex, temephos, mosquito larvicidal oil, pyrosine oil and parisgreen were evaluated for the control of *Anopheles culicifacies*, the principal malaria vector in Haryana state of India. There was 37.5% decline in the density of *Anopheles culicifacies* during larviciding and 43.2% decline in the incidence of malaria in Gurgaon urban. Mosquito larvicidal oil applied at 1 lit/ 50 linear yards was highly effective against *Anopheles culicifacies* larvae.

(Key words: larvicidal impact, malaria vector, *Anopheles culicifacies)*

INTRODUCTION

It is a well recognized fact that in any consideration of the control of arthropod-transmitted disease, malaria stands alone. The history of malaria in India is largely a history of the control of *Anopheles culicifacies*. *Anopheles culicifacies* has become resistant to malathion in a few districts of Gujarat and Maharashtra states (RAO. 1981). An excellent review of litrature on the biology of *Anopheles culicifacies* till 1940 was by AFRIDI & PURI (1940), followed by a second article on original observations (AFRIDE, MAJID & IMDAD ALI SHAH (1940). The article by BHATIA & KRISHNAN (1961) in the 'Malaria vectors in India' is full of valuable information. Baytex, temephos and pyrosine oil have been evaluated as larvicide against *Anopheles* and culicine mosquitoes by WATTAL *et al.* (1975). Parisgreen was tested against mosquito larvae by VITTAL *et al.* (1981). An economic feasible method i. e., anti-larval operations by different larvicides would seem to be good approach for the control of malaria and vector *Anopheles culicifacies* as discussed in this paper.

MATERIALS AND METHODS

The test site was located in South-western Delhi known as Gurgaon urban having 92,618 inhabitants. The breeding sites of *Anopheles culicifacies* consisted of pits, drains, wells, overhead tanks and reservoirs. As the community has undergone urbanization, the house tanks also served as a breeding ground for *Anopheles culicifacies*. The climate of Gurgaon was wet and dry and rainfall ranged between 1—1-0 mm. The relative humidity ranged between 35—60 per cent. Thirty catching stations were fixed for *Anopheles* collection at peripheral and central zone of the town. The malaria positive cases were reported before one year of commencement of anti-larval operations to monitor the impact of larvicides. Mosquito larvicidal oil (MLO) was used (1 lit/50 linear yards) in standing water where layer of oil was possible and pyrosine oil (2 lit/500 linear yards) in breeding places with high organic pollution. Temephos

(2.5 ml/500 linear yards) was used only in drinking water while baytex (5 ml/500 linear yards) in grassy pits and ponds. Parisgreen was used in the form of pellets (1 ball/5 sq ft). The pellets were prepared from 1 part of clay, 5 parts sand and 1 part of parisgreen. Pyrosine oil, baytex and temephos were sprayed by knap-sac pumps. MLO was sprayed by mop and bucket method.

RESULTS AND DISCUSSION

The annual blood Examination rate (ABER), annual parasite incidence (API) and slide positivity rate (SPR) before and after anti-larval operations are given Tdble 1. The percentage change in mean vector densities during larviciding are shown in Table 2. The consumption of different larvicides and man/days for larviciding are given in Table 3. Mosquito larvicidal oil showed 100% mortality upto two weeks (Table 4). Before larviciding the adult resting density for *A. culicifacies* averaged 16.3 per man hour which was reduced to 9.2 per man hour after larviciding. There was 43.2 decline in vector density. It would appear from Table 1 that in 1979, out of 26,647 blood smears examined 1066 were found to be positive for malaria. *Plasmodium vivax* was a common infection during the study. Out of 16,968 blood slides examined 367 were positive for *Plasmodium vivax* infection after larviciding in 1980. Out of 16,968 blood slides. 1 was also positive for *Plasmodium falciparum* in 1980. In 1979 the parasite rate was 4.03% while it

TABLE 1. Malariometric survey before and after larviciding.

Year	No. of slides examined	Positives Pv.	Pf.	Parasite Rate	ABER* %	API** %	SPR*** %
1979	26,647	1,066	—	4.03%	41. 1	12. 9	4. 3
		AFTER LARVICIDING					
1980	16,968	367	1	2.1%	19.23	4.17	2.16

* ABER (Per hundred population)
** API (Per thousand population)
*** SPR (Per hundred slides examined)

TABLE 2. Percentage change in amn vector densities before & after larviciding.

Parameter	*Anopheles culicifacies* Before larviciding (Jan. to Dec. 1979)	After larviciding (Jan. to Dec. 1980)
Mean density	16.2	9.2
% change	—	43.2

TABLE 3. Comparison of the amount of larvicides used for breeding of *Anopheles culicifacies*.

Month (1980)	MLO (lit)	Larvicides Baytex (lit)	Pyrosine oil (lit)	Temephos (ml)	Paris green (kg)	Man/days used for larviciding
Jan	975	1.30	4	50	—	81
Feb	965	1.14	10	48	—	72
Mar	1090	.79	—	47	—	78
Apl	1233	.75	—	40	—	78
May	895	.84	—	40	—	75
June	1077	.85	20	38	—	78
July	2460	2.64	30	49	25	81
Aug	2275	2.60	25	45	—	81
Sept	2425	2.85	15	40	—	78
Oct	2435	2.72	10	44	—	75
Nov	2300	1.74	—	39	—	78
Dec	2445	1.93	—	44	25	75

TABLE 4. Result of anti-larval treatment during 1980.

Larvicides	Dosage/Area treated	*Anopheles culicifacies*		
		I week	II week	III week
Baytex	5 ml/500 lin yards	—	+	+
Temephos	2.5 ml 500 lin yards	—	+	+
Parisgreen	1 ball/5 sq ft	—	+	+
Pyrosine oil	1 lit/250 lin yards	—	+	+
Mosquito larvicidal oil	1 lit 50 lin yards	—	—	+

— — = Larval mortality (100%).
— = Larval mortality (80%)
\+ = No mortality.

reduced to 2.1% after larviciding in town. It is evident from epidemilogical data that annual parasite incidence (API) being 12.9 during 1979 and declined to 4.17 in 1980 after larviciding. Similar entomological observations as recorded here, were also reported by WATTAL *et al.* (1975). As for as effectiveness was concerned, mosquito larvicidal oil (1 lit/50 lin yards) gave 100% kill and effect usually lasted up to two weeks. The effect of temephos, pyrosine oil and parisgreen lasted for one week only. The trial showed that application of baytex, temephos, parisgreen, mosquito larvicidal oil and pyrosine oil could effectively control the vector density, as well as malaria incidence.

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STUDIES ON THE ACTIVITY OF SOME INSECT POLLINATORS ON JUJUBE (*ZIZYPHUS MAURITIANA* LAMK.)

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Incidence and activity of pollen carrying insects were studied on *Zizyphus mauritiana* Lamk. Honey bees and other Hymenopteran insects were more active on upper branches. House flies and other Dipteran insects were abundant on middle and lower branches. Honey bees were more efficient pollen carriers while frequency of visit of houseflies to receptive flowers was more.

(Key words: insect pollinators, jujube, *Zizyphus mauritiana)*

INTRODUCTION

Ber (Zizyphus mauritiana Lamk.) is an insect pollinated plant. Honey bee, yellow wasp and house fly have been reported as pollinators for *ber* (DHALIWAL, 1975; TEAOTIA & CHAUHAN, 1964). A number of insects were seen associated with these plants during the flowering season at the Central Research Farm, Central Arid Zone Research Institute, Jodhpur. The insects found active in transportation of *ber* pollen, their abundance, frequency of visits, and efficiency as pollinating agents have been studied and reported in this paper.

MATERIALS AND METHODS

The insects visiting *ber* flowers were collected by sudden trapping with polythene bags (25 cm × 45 cm), anaesthetized with ethyl acetate and observed individually for the presence of *ber* pollen, by dipping them in 70% ethyl alcohol. Only those insects which bore *ber* pollen were considered in further studies.

Observations for time of appearance and of maximum activity were made for the major species selected by considering their relative abundance on *ber* flowers. Abundance was defined by the number of insect specimens collected during one hour time each in the morning (8-9 AM), noon (12-1 PM) and afternoon (3-4 PM).

Pollination efficiency of the insects was ascertained in terms of the frequency of visits per hour and the duration of stay or contact with flowers. Since the *ber* flowers remain recepetive for pollination only for a period of 24 hours after opening, the freshly opened flowers alone were considered for the studies. For counting the visits 30 cm long portions of upper, middle and lower branches of *ber* plants were demarcated by tagging them and the visits were recorded by visual observation.

RESULTS AND DISCUSSION

The insects found transferring pollen in *Zizyphus mauritiana* are listed in Table 1. Number of butterflies observed was too low and hence these were omitted in the studies.

Data on the abundance of insect pollinators at different periods of the day are presented in Table 1. Hymenopteran insects except honey bees were not observed in the morning. These were more abundant around noon. In the afternoon also their density was low.

Dipteran insects though present in the morning, were more abundant around noon and afternoon.

Frequency of visit of the major pollinators is shown in Table 2. Hymenopteran insects were dominant on upper branches whereas the dipterans were found more active at the lower and middle branches. House flies, honey bees and otitids were more frequent visitors. Of these honey bees and house flies were largely responsible for the transmission of *ber* pollen. The otitids, though were more frequent visitors, did not carry much of pollen. DHALIWAL (1975) and TEAOTIA & CHAUHAN (1964) also had reported honey bees and house flies as principal pollinator insects for

TABLE 1. Insect pollinators of *Zizyphus mauritiana* Lamk. and their relative abundance.

Insect	No. of specimens collected			
	Morning (8–9 hrs)	Noon (12–13 hrs)	Afternoon (15–16 hrs)	Mean/hour.
ORDER DIPTERA				
Fam. Calliphoridae:				
Chrysomyia rufifacies	4.67	3.67	9.33	5.89
Fam. Muscidae:				
Musca domestica L.	18.67	47.00	22.33	29.33
Fam. Otitidae:				
Physiphora aenea (Fabr.)				
Physiphora demandata (Fabr.)	16.67	55.33	34.00	35.33
Fam. Sarcophagidae:				
Sarcophaga sp.	7.33	8.33	5.67	7.11
Fam. Syrphidae				
Allobaccha sarphirhina Wieldmann	3.00	2.00	7.33	4.11
Eristalinus sp.	4.33	9.00	12.33	8.55
ORDER HYMENOPTERA				
Fam. Apidae:				
Apis indica	7.00	44.67	18.33	23.33
Apis sp.	1.33	3.33	—	1.55
Fam. Eumenidae:				
Delta campaniforme esuriens F.	—	6.33	2.67	3.78
Fam. Halictidae:				
Nomioides variegatus (01)	2.33	6.33	2.67	3.78
Fam. Sphecidae:				
Chalybion bengalense (Dahlbom)	—	6.67	1.67	2.78
Oxybelus lamellatus Olivier	2.67	5.33	4.33	4.11
Philanthus basalis F. Smith	—	6.67	3.33	3.33
Sceliphron madraspatanum pictum (F. Smith)	4.67	6.33	1.33	4.11
Fam. Scolidae:				
Campsomeriella collaris (Fabr.)	—	8.33	2.33	3.55
Fam. Tiphidae:				
Iswara luteus Westwood	—	4.67	1.67	3.11
Fam Vespidae:				
Vespa orientalis Fabr.	—	4.33	1.67	2.00

TABLE 2. Frequency of visit of major insect pollinators of *Zizyphus mauritiana* Lamk. at different periods of the day.
(Means of the observations for three weeks)

S. N.	Insect		Visits per hour				No. of receptive flowers	Visits per receptive flower
			8–9 Hours	12–13 Hrs	15–16 Hrs	Mean		
1.	*Apis indica*	U*	14.33	46.33	31.0	30.55	11	2.78
		M	12.67	43.67	27.33	27.89	9	3.10
		L	6.33	34.00	15.00	18.44	8	2.30
2.	*Chrysomyia rufifacies*	U	3.67	4.67	6.33	4.89	6	0.82
		M	6.67	4.00	6.67	5.78	8	0.72
		L	13.33	17.67	20.00	17.00	8	2.13
3.	*Eristalinus* sp.	U	7.33	4.67	6.33	6.11	6	1.02
		M	18.33	17.67	20.00	19.33	8	2.42
		L	17.33	22.00	34.33	24.55	6	4.09
4.	*Musca domestica*	U	12.33	19.00	26.67	19.33	8	2.42
		M	52.33	58.00	37.33	49.22	8	6.15
		L	87.67	86.33	104.00	92.67	6	15.45
5.	*Physiphora* spp.	U	24.33	27.33	31.67	27.78	9	3.09
		M	37.33	42.33	47.33	42.44	7	6.06
		L	49.33	68.67	61.67	59.89	7	8.56
6.	*Sarcophaga* sp.	U	2.67	2.33	7.33	4.11	8	0.51
		M	14.33	17.00	13.33	14.89	9	1.65
		L	8.33	14.67	12.67	11.89	6	1.98
CD (P = 0.05)		U	2.39	5.34	2.65			
		M	11.38	9.36	5.49			
		L	8.75	8.50	6.96			

*U = Upper branch (30 cm portion)
M = Middle branch (,,)
L = Lower branch (,,)

Zizyphus mauritiana. Whereas *Chrysomyia*, *Eristalinus*, *Physiphora* and *Sarcophaga* visited all the flowers regardless of their receptivity, honey bees and house flies visited mostly the receptive flowers, although older flowers were also visited.

Most of the insects, except house fly, appeared after 8 AM. Maximum activity of honey bees was recorded between 11.30 AM to 3.15 PM. TEAOTIA & CHAUHAN (1964) had reported similar observations. House flies and other Dipteran insects which were more abundant on lower and middle branches, exhibited maximum activity in the afternoon. Honey bees were found to be active on upper branches as well. Of all the insects observed, house fly was found to be active for maximum time in the day (7.30 AM to 6.30 PM), whereas the honey bee's span of daily activity was the shortest (8.30 AM to 4.15 PM).

The flowers opening in the morning were exposed more to house flies and therefore mostly got pollinated by them. Contribution of honey bees was more

in pollination of cultivars like *Gola* and *Mundia* where anthesis occurred around 12—13 hr (VASHISHTHA & PAREEK, 1979).

Hony bees were found to be more efficient carriers of pollen, but their activity was restricted to a limited time in the day and the number of visits per flower (Table 2) was also less. In contrast, the activity of house flies was spread to a longer duration and their frequency of visit was also more. However the time of actual contact or stay on the flowers was very short. Flowers opening early in the season were exposed mostly to house flies, since the honey bees appeared only when full bloom set in.

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USE OF INSECTICIDES FOR THE CONTROL OF *PLANOCOCCUS PACIFICUS* COX, A MEALY BUG ON CUSTARD APPLE

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Use of some modern insecticides was tested against a new mealy bug pest of custard apple, *Planococcus pacificus* Cox in laboratory and field studies during 1980. Dimethoate, phosphamidon, monocrotophos and dichlorvos at 0.05% were found effective in controlling the pest. The synthetic pyrethroids permethrin, fenvalerate and cypermethrin at 0.02% were poor in effectiveness. Carbaryl 0.2% gave good results in the laboratory experiment only. Sprays of 0.05% phosphamidon and dichlorvos are recommended for the effective control of *P. pacificus*.

(Key words: custard apple, *Planococcus pacificus* Cox, insecticidal control)

INTRODUCTION

The custard apple, *Annona squamosa* is cultivated in Andhra Predesh, Maharashtra, Gujarat, Madhya Pradesh, Karnataka, Bihar, Assam and occupies an area of about 46,000 hectares (VEVAI, 1971). During 1980-1981 the mealy bug, *Planococcus pacificus* Cox (Pseudococcidae) was found to occur as a serious pest from July to October in Karnataka. The attacked fruits remained small in size and shrivelled. Honey dew excreted by the mealy bugs favoured development of sooty mould which spoiled the fruit quality and rendered them unmarketable. Results of studies conducted to evaluate the use of some modern insecticides for controlling the pest are reported in this paper.

MATERIALS AND METHODS

In the laboratory evaluation experiments moving adult female bugs of uniform age group collected from the field and maintained in the laboratory were used. Every care was taken in collection not to damage bugs. The moving females were put on fresh fruits kept at 27 ± 1°C temparature and 75 ± 5% relative humidity. Ten insecticides in their commercial formulations were tested in these studies (see Table 1). The untreated check (control) was sprayed with water. Each treatment was replicated thrice using 25 mealy bugs per replication. The bugs were exposed to insecticide films made on petridishes (9 cm diam) by spraying with 1 ml of insecticide per dish under Potter's tower. After exposing the bugs to the films for 30 minutes they were transferred to fresh fruits and kept under the controlled conditions. Mortality response was recorded one and four days after treatment. Percentage mortility was corrected using Abbotts's formula (ABBOTT, 1925) and then transformed to arc sin values before subjcting to analysis of variance.

The field experiment was laid out in 1980 in a randomized block design having ten treatments replicated thrice. Pre-treatment counts of mealy bug population was taken one day before insecticide application and post-treatment counts one and seven days after treatment from three randomly selected fruits per replication of the treatments. The insecticides (see Table 2) were sprayed by

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TABLE 1. Relative contact toxicity of insecticides to adults of *P. pacificus*.

Insecticide and conc. (ai %)	Mean corrected per cent mortality (in days after spraying)	
	1	4
Permethrin, 0.02	10.00 (18.38)^{e}	57.33 (49.22)^{b}
Fenvalerate, 0.02	11.33 (19.48)^{e}	43.33 (41.01)^{c}
Cypermethrin, 0.02	19.33 (26.08)^{d}	62.33 (52.15)^{b}
Carbaryl, 0.2	16.67 (23.98)^{de}	100.00 (90.00)^{a}
Dichlorvos, 0.05	100.00 (90.00)^{a}	100.00 (90.00)^{a}
Endosulfan, 0.05	29.33 (32.78)^{c}	55.33 (48.13)^{b}
Dimethoate, 0.05	100.00 (90.00)^{a}	100.00 (90.00)^{a}
Phosphamidon, 0.05	30.00 (33.00)^{c}	100.00 (90.00)^{a}
Monocrotophos, 0.05	50.00 (45.00)^{b}	100.00 (90.00)^{a}
Quinalphos 0.05	28.33 (32.02)^{c}	100.00 (90.00)^{a}
C D (5%)	(6.42)	(5.07)

Figures in parenthesis are arc sin (Sin$^{-1}\sqrt{x}$) values. Treatment means followed by the same alphabet are not statistically significant at P = 0.05.

TABLE 2. Control of *P. pacificus* on custard apple when treated with insecticides in the field.

Insecticide and concentration (ai %)	Pre-treatment population (mean no. of insects per fruit)	Mean per cent reduction in mealy bug population over pre-treatment population (in days after spraying)		Treatment cost/plant/spray (Rs)
		1	7	
Permethrin, 0.02	175.00	18.33 (25.34)^{b}	34.00 (35.63)^{bc}	1.63
Fenvalerate, 0.02	248.33	14.33 (22.11)^{b}	34.33 (35.85)^{bc}	1.35
Cypermethrin, 0.02	208.33	17.67 (24.82)^{b}	44.00 (41.54)^{bc}	2.16
Carbaryl, 0.2	207.67	10.00 (18.41)^{b}	20.67 (27.00)^{c}	0.58
Dichlorvos, 0.05	130.00	100.00 (90.00)^{a}	100.00 (90.00)^{a}	0.23
Endosulfan, 0.05	156.67	13.33 (21.27)^{b}	29.67 (32.94)^{bc}	0.41
Dimethoate, 0.05	250.00	100.00 (90.00)^{a}	100.00 (90.00)^{a}	0.32
Phosphamidon, 0.05	190.00	36.67 (28.08)^{b}	100.00 (90.00)^{a}	0.49
Monocrotophos, 0.05	174.00	94.67 (76.89)^{a}	97.67 (82.98)^{a}	0.68
Quinalphos, 0.05	171.67	23.33 (28.24)^{b}	58.33 (49.80)^{b}	0.63
Control (water spray)	108.33	191.33*	227.33*	—
CD 5%		(14.68)	(14.80)	

Figures in parenthesis are arc sin (Sin$^{-1}\sqrt{x}$) values. Treatment means followed by the same alphabet are not statistically significant at P = 0.05 level. *Figures in control denotes the number of mealy bugs present which were not included in statistical analysis.

the high volume foot sprayer using 3 litre of spray fluid per plant. The per cent reduction in mealy bug population due to the treatment was calculated for analysiss. The cost of various treatments was also calculated to ascertain the economics of control measure based on prevailing market price of insecticides.

RESULTS AND DISCUSSION

Results of laboratory evaluation of the insecticides (Table 1) show that in one day of exposure to the insecticide films dimethoate and dichlorvos recorded 100 per cent mortality of the mealy bug: monocrotophos gave 50 per cent mortality. The other insecticides gave significantly low and poor effect. Four days after treatment however, dimethoate, phosphamidon, monocrotophos, dichlorvos, carbaryl and quinalphos gave complete kill of the insect. Endosulfan and the synthetic pyrethroids gave 43.33 to 62.33 per cent mortality.

In the field studies dimethoate and dichlorvos gave cent per cent reduction in population in 1 day following application; monocrotophos also giving comparable result with 94.67 per cent reduction. All the others were significantly less effective. After 7 days of spraying again phosphamidon showed absolute control in addition to dimethoate, dichlorvos and monocrotophos.

From the results presented dimethoate, phosphamidon, monocrotophos and dichlorvos have emerged as the most effective insecticides for the control of *P. pacificus* on custard apple. From cost consideration (Table 2) phosphamidon and dichlorvos are advantageous.

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BRIEF COMMUNICATION

HOST PREFERENCE OF SPOTTED BOLLWORMS *EARIAS* SPP. (LEPIDOPTERA : NOCTUIDAE)

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(Received 31 October 1983)

Six common host plants *Earias* spp. viz., Cotton (*Gossypium hirsutum* Linnaeus), *bhendi* (*Hibiscus abelmoschus* Linnaeus), holyhock (*Althoea rosea* Cav.), *pundi* (*Hibiscus cannabinus* Linnaeus), *Hibiscus panduraeformis* Burm and *Abutilon indicum* G. Den. were evaluated for the feeding, oviposition preference and also for determining fecundity and longevity. Under natural infestation (planted to obtain synchronised flowering and fruiting) maximum damage to fruits was caused in *bhendi* (60.68 per cent) followed by cotton (5.74 per cent) and holyhock (2.90 percent). Under laboratory conditions the least developmental period was found to be on *bhendi* (23.50 days) followed by cotton (25.40 days) and holyhock (27.50 days). Moths emerging from larvae reared on *bhendi* had the highest fecundity (468 eggs per female) followed by cotton (303.20 eggs per female) and *pundi* (208 eggs per female). Under free choice oviposition in cages *bhendi* was the most preferred host for oviposition receiving 35.33 eggs followed by cotton (28.00 eggs), *H. panduraeformis* (20.66 eggs) and *A. indicum* (18.00 eggs), when *Sida cardifolia* Linn. was also included along with above mentioned six host plants. From the studies it is suggested to use *bhendi* to trap *Earias* spp. in cotton fields.

(Key words: host preference, Earias spp.)

The pest status of a particular insect depends on its ability to breed on a variety of host plants, comparitive growth rate, fecundity, population dynamics and distribution (ANANTHAKRISHNAN, 1977). The spotted bollworms *Earias vittella* (Fabricius) and *E. insulana* (Boisduval) exhibit marked preferences for various host plants (VEDAMOORTHY & REED, 1977) and they are known to attack 38 plant species (HIREMATH, 1976). Information on the most preferred host plant is of importance as it can be used as trap crop (BURT, 1916: FLETCHER, 1918). Moreover the preferred hosts have a great influence on oviposition (KHAN & RAO, 1960), fecundity, developmental period and adult longevity. Their presence or absence should be taken into account in any pest management progromme.

Three different experiments were conducted to study the host preference of *Earias* spp. on the Agricultural College farm Dharwad during 1974—1975.

In the first experiment six species of host plants of *Earias* spp. viz., Cotton (*Gossypium hirsutum* Linnaeus), *bhendi* (*Hibiscus abelomoschus* Linnaeus), holyhock (*Althoea rosea* Cav.), *pundi* (*Hibiscus cannabinus* Linnaeus), *Hibiscus panduraeformis* Burm and *Abutilon indicum* G. Den. were sown planted during *kharif* 1974 in the plot (2.5×3.0 m) so as to

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get synchronised flowering and fruiting in all the hosts. The seeds of cotton, *bhendi,* holyhock and *pundi* were sown whereas 30—40 day old seedlings of *H. panduraeformis* and *A. indicum* were planted. There were four replications. The fruiting bodies in all the plants damaged by the spotted bollworms were recorded and the percentage of damage was worked out.

In the second experiment, *E. vittella,* the dominant species of spotted bollworms in Dharwad (HIREMATH, 1976) was reared on the fresh and tender fruiting bodies of these six host plants during August-September, 1974. Twenty-five newly hatched larvae were individually reared in specimen tubes (2.5 × 7.5 cm) on fruiting bodies of each of host plant. There were four replications. The food was changed daily, and obsevations were made on the larval and pupal durations as also fecundity and longevity of adults. Adults were provided with 10 per cent honey as food. The maximum and minimum temperature of 32.80 and 24.07°C and a mean relative humidity of 80.18 per cent prevailed during the period of study in the laboratory.

In the third experiment, fresh stalk (0.25 to 0.3 m in length) of each host bearing all the reproductive parts like squares, flowers and bolls/fruits of each of the host plant including that of *Sida cardifolia* Linnaeus was provided in the wire mesh cage (1 × 1 × 1 m). Three such cages representing three replications were maintained. Four pairs of fresh moths were released in each cage. The stalks were changed every day and the number of eggs laid on each host plant were recorded till the death of all the moths released in all cages.

Natural incidence in field: In the field, the incidence of only two species viz., *E. vittella* and *E. insulana* was evident. The infestation on the fruiting bodies of different host plants planted in the field varied from 0.10 to 60.68 per cent (Table 1). It is also evident that *bhendi* was the most preferred

TABLE 1. Damage by *Earias* spp. under natural field conditions and ovipositional preference of *E. vittella* on different host plants.

Host plants	Mean damaged fruiting bodies (%)	Mean number of eggs laid/stalk
Gossypium hirsutum L.	5.74	28.00
Hibiscus abelmoschus L.	60.68	35.33
Althoea rosea Cav.	2.90	13.00
Hibiscus cannabinus L.	0.80	2.00
Hibiscus panduraeformis Burn.	0.10	20.66
Abutilon indicum G. Den.	0.10	18.00
Sida cardifolia L.	—	1.00
SE ±	—	5.23
CD @ 5%	—	11.20

host with 60.68 per cent fruiting bodies infested followed by cotton and holyhock. Similar observations were made by BURT (1916, 1918) and FLETCHER (1918).

Influence on larvae and adult stages: The development perrod of *E. vittella* varied with the host (Table 2). The total life cycle was from 22 to 32 days in different hosts. The life cycle was shortest when the larvae were reared on *bhendi* (23.5 days) followed by cotton (25.40 days), holyhock (27.50 days), and *pundi* (27.80 days). It is also clear that the larval and pupal periods were shortest in case of *bhendi*. These observations are in agreement with the finding of DESHPANDE & NADKARNY (1936), KHAN & RAO (1960), SOHI (1964) and GREWAL & ATWAL (1969). MEGAHED *et al.* (1973) also studied the biology on unripe cotton, *bhendi* and maize seeds and noticed that the shortest life period was on *bhendi* seeds. The percentage of larvae reaching adult stage was maximum (88.0) in *bhendi* followed by cotton (78.0). The percentage of mortality of larvae was maximum in case of *A. indicum* (59.0), whereas it was minimum on *bhendi* (12.0).

The longevity of male moths varied from 6 to 14 days with marked variation from host to host. The male moths emerged from the larvae fed on *bhendi* fruits lived for longer period (11.7 days) followed by cotton, holyhock and *pundi*. The longevity of moths emerged from the larvae reared on *H. panduraeformis* was the least (7.00 days). Similarly in case of female moths also *bhendi* as pre-imaginal food influenced the longevity (17.7 days) followed by holyhock (14.7 days), and cotton (14.00

TABLE 2. Effect of host plants on development, longevity and fecundity of *Earias vittella* (F.) adults.

Host plants	Larval period (days)	Pupal period (days)	Adult longevity (days) male	Adult longevity (days) female	Fecundity eggs/ female
Gossypium hirsutum L.	13.70[x] (12–15)[xx]	12.60 (10–13)	8.2 (7–10)	14.0 (13–15)	303.2 (285–324)
Hibiscus abelmoschus L.	10.20 (9–11)	9.60 (9–10)	11.7 (10–14)	17.7 (17–18)	469.7 (435–524)
Althoea rosea Cav.	14.20 (12–16)	12.70 (10–13)	8.2 (7–10)	14.7 (14–15)	188.2 (156–207)
Hibiscus cannabinus L.	14.50 (12–16)	12.80 (10–13)	8.2 (8–9)	13.7 (13–14)	208.0 (166–234)
Hibiscus panduraeformis Burn.	15.00 (12–17)	13.00 (12–14)	7.0 (6–8)	13.2 (13–14)	180.2 (160–219)
Abutilon indicum G.Den.	14.80 (12–17)	13.00 (12–14)	7.7 (6–9)	12.2 (12–13)	168.7 (159–176)

x Mean
xx Range

days). MURTUZA & WAHEED (1968) also reported that the adults lived for 15 days on *bhendi*. The level of egg production per female was maximum in the moths emerged from larvae reared on *bhendi* (409.7 eggs) followed by cotton (303.2 eggs) and is in agreement with the reports of DESHPANDE & NADKARNY (1936), KHAN & RAO (1960) and MEHTA (1971). The maximum egg laying period was 16 days in case of *bhendi* followed by holyhock (12 days), *pundi* (12 days) cotton (11 days).

Ovipositional preference: The number of eggs laid by *E. vittella* moths on the host stalks varied from 1.0 to 35.33 (Table 1). Among the host plants tested the highest number of eggs was laid on *bhendi* (35.33) followed by cotton (28.00), *H. panduraeformis* (20.66) and *A. indicum* (18.00).

From these studies, it is evident that *bhendi* is the most preferred host followed by cotton whereas *A. indicum H. panduraëformis* and *S. cardifolia* are least preferred hosts. Hence, *bhendi* may be used as trap crop in cotton fields and the removal of *A. indicum*, *H. panduraeformis* and *S. cardifolia* will help in lowering the incidence of spotted bollworms in cotton fields.

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BRIEF COMMUNICATION

EVALUATION OF FENITROTHION FOR THE CONTROL OF MALARIA VECTOR *ANOPHELES CULICIFACIES* AND OTHER ANOPHELINES (DIPTERA : CULICIDAE)

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(Received 26 February 1984)

During the epidemic of malaria in Said Pur village, Gurgaon district, an entomological study was made. Fenitrothion was evaluated against malaria vector *Anopheles culicifacies* and other Anophelines in this village. There was 91.12% decline in vector density after fenitrothion spray.

(Key words: fenitrothion, vector, anopheline)

Fenitrothion shows promise as a substitute for chlorinated insecticides in the control of malaria and malaria vector whenever the latter are unsuitable because of *Anopheles* resistance. A village scale trial of fenitrothion was carried out in September, 1983, covering a population of about 702 in Saidpur village. All human dwellings and cattle sheds were sprayed with fenitrothin at 100 mg/sq. feet. Entomological evaluation results showed an excellent control of *Anopheles culicifacies* (91.12% reduction) the malaria vector in Saidpur village.

In recent years DDT has failed to control malaria in many states of India, because of resistance to the vector *Anopheles culicifacies*, to this insecticide. Continuing malaria transmission in many DDT sprayed area indicates this insecticide is no longer operationally effective in such areas, therefore, the efficacy of alternative insecticide is being investigated. One of the most promising alternative insecticides under investigation is fenitrothion. JOSHI *et al.* (1977 a) carried out a village scale trial of this insecticide near Semarang, central Java. PRADHAN *et al.* (1979) carried out a house-scale trial of fenitrothion at the reduce dosage of 1g/m² in central Java. In order to reduce the amount of insecticide used and treatment costs, SUPRATMAN *et al.* (1979) tested fenitrothion against *Anopheles aconitus* in central Java, Indonesia.

This trial was carried out in Saidpur village, about 15 km from Gurgaon city. An epidemic of malaria occurred in this village in September, 1983. The trial village comprised 80 human dwellings, 23 cattle sheds and a population of 702. The houses are small and constructed of mud and stones with thatched roofs. A fenitrothion 40% water dispersal powder (wdp) formulation was applied at a target dosage of 100 mg/sq feet with Hymetic sprayers fitted with pressure gauges and nozzle tips, having initial discharge rate of 740—857 ml/minute. The interior walls and ceilings of the house were sprayed to a height of 2 m as well as undersides of furniture and horizontal surfaces. Cattle shelters and all out-houses were also sprayed. Spraying

done by two squads, each with five Spraymen and Sanitary Supervisor. Only one round of fenitrothion residual spray was applied. The following types of mosquito collection were made: nocturnal (6 PM to 10 PM) resting density indoors and outdoors: and diurnal 6.30 AM to 8.30 AM) resting in human dwellings and cattle sheds. Density of mosquitoes were reported as number per-man hour. The collection was made by one Insect Collector with aspirator tube and torch light.

The man-hour pre- and post-spray densities for *Anopheles culicifacies*, *Anopheles subpictus*, *Anopheles stephensi* and *Anopheles annularis* are given in Table 1. There was 91.12% decline in *Anopheles culicifacies* density. Reduction in *Anopheles stephensi* densities in evaluation village after spray was 91.3%. Reduction in *Aaopheles subpictus* and *Anopheles annularis* resting densities based on pre-spray densities in evaluation village was 100%. Reduction in malaria vector *Anopheles aconitus* densities (70—95%) was observed by BANG *et al.* (1981) in Java after selective application of fenitrothion. The trial showed that fenitrothion could effectively control the malaria vector *Anopheles culicifacies* and other anophelines.

TABLE 1. Percentage reduction in the mean densities of different mosquitoes in the evaluation village.

Species	Time spent (Hours)	Pre-spray density	Post-spray density	% reduction
An. culicifacies	1	45	4	91.12
An. subpictus	1	40	nil	100
An. stephensi	1	92	8	91.31
An. annularis	1	2.3	nil	100

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CHANGES IN THE FUNCTIONAL RESPONSE OF INSTARS OF *DIPLONYCHUS INDICUS* VENK. & RAO (HEMIPTERA : BELOSTOMATIDAE) IN ITS PREDATION OF TWO SPECIES OF MOSQUITO LARVAE OF VARIED SIZE

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Five predator instars of the water bug, *Diplonychus indicus* Venk. & Rao (Hemiptera: Belostomatidae), when exposed to four size classes of two different prey species of larval mosquitoes-*Aedes aegypti* and *Culex fatigans* at varying densities, showed the type II functional response in the increasing attack rate *(a)* corresponding to decreasing handling time (T_h). Largest predator instar (V) killed maximum number of smallest prey (1st) and vice versa of both prey species. Larger predator instars showed more successful attack and shorter handling time than smaller predator instars. However, changes in functional response were observed in the instars II and III of *D. indicus* preying on 2nd and 3rd size classes of *A. aegypti* and *C. fatigans*. The variations with relation to the observation of selective predation are discussed.

(*Key words:* prey selection, functional response, biological control)

INTRODUCTION

The functional response is the change in the number of prey attacked per predator with variation in prey density assuming that the predators search at random for a homogeneous prey population. It is determined by two para meters: namely attack rate or rate of successful search *(a)* and handling time (T_h) (HOLLING, 1959, 1961; HASSELL *et al.*, 1976). The values of a and T_h vary with the relative sizes of predator and prey, and the predator efficiency. THOMPSON (1975) measured a and T_h for older nymphal instars of the damsel fly *Ischnura elegans* (van der Lind.) attacking different size classes of *Daphnia magna* (Straus). MCARDLE & LAWTON (1979) measured a and T_h of several instars of *Notonecta glauca* attacking four full size classes of *D. magna*. In the present study, we compared the functional response of different instars of the water bug *Diplonychus indicus* preying on four prey size classes of *A. aegypti* and *C. fatigans*.

MATERIAL AND METHODS

Diplonychus indicus females deposit fertilized eggs on the dorsum of males in the form of egg pads for brooding. Such encumbered males were collected from local ponds. The emerging instars from these egg pads were reared in the laboratory under constant light at 28°C and fed on mosquito larvae, as suggested by SMITH (1976). *D. indicus* like other water bugs has five nymphal instars before it becomes adult. The total body length of 25 individuals of each instar was measured from the tip of the head to the base of the abdomen and the mean values

were given in the table. The predator instars were given abundant prey for 24 h befors the functional response trials to ensure satiation. To avoid the influence of reproductive cycle and migratory activity of the predator on predation, only nymphal instars of the predator were included in the present study.

Larvae of *Ae. aegypti* and *C. fatigans* were reared in the laboratory and the four size classes were separated, based on total body length.

The functional response of each of the five instars of *D. indicus* was measured for all four size classes of both prey species. To determine the functional responses, the number of prey that a single predator killed during a one hour trial was recorded for 5 replicates of five initial prey densities. Prey densities were 5, 10, 20, 40 and 80 per 500 ml of water in a 500 ml beaker. All trials were carried out at 28°C ± 1°C under constant light. The prey density of each prey species was varied keeping the density of the predator as one per container. The attacked prey were easily distinguished from those dying naturally and from moulted exuviae by their distorted shape and dark colour. The natural mortality was negligible.

Based on the assumption that the coefficients of the 'Disc equation' are constant and independent of prey density or feeding rate, the attack rate a and handling time T_h were calculated using the 'modified random predator equation' of ROGERS (1972):

$$N_a = N\,1 - \exp\,[-a\,(PT - N_a T_h)]$$

where N_a = the number of prey killed; P = the number of predators; N = the density of the prey; a = a constant, the attack rate of the predators, which is a function of the reactive distance of the predator, the speed of movement of predator and prey and the proportion of successful attack and T_h = a constant, the handling time of the predator that includes the time spent in pursuing, subduing, eating and digesting each prey. To avoid the experimental errors associated with the estimation by linear regression, a and T_h were estimated by the non-linear least square method.

RESULTS

Prey death rate

Data ore give in Table 1. Predator instar II showed similar predatory efficiencies on all prey size classes of *A. aegypti*, whereas instar IV killed more of all size classes of *C. fatigans*. The predators killed more *Aedes* than *Culex* larvae as the former are larger. Predator instars II and IV killed maximum number of larvae of *Aedes* and *Culex* respectively. The functional response showed by each class of predator and prey exhibited typical type II functional response at prey densities between 40 and 80 per 500 ml.

Predator instar I killed equal number of all size classes of both prey species, whereas predator instar II preferred more of smaller size classes of *Aedes* larvae than all size classes of *Culex*. Predator instars III and IV restricted their preference to 1st and 2nd size classes of both species. Instar V uniformly preyed all size classes of *Aedes* than *Culex* larvae. N_a was comparatively high in predator when exposed to *Aedes* larvae.

1st and 2nd prey size classes (both prey species) were killed more by larger predators IV and V. Third and 4th prey size classes of *Aedes* larvae were killed more by predator instar II, whereas 3rd and 4th size classes of *Culex* larvae were killed more by IV and V predator in stars. The variation in N_a due to difference in prey species may be correlated with the size, stratal distribution and palatability of the prey.

Attack rate and handling time

The values of a and T_h are shown in Table 1. Data reveals that attack rate is very high in all predator instars,

TABLE 1. Results of the functional response experiments of the instars of the predator *D. indicus* when exposed to two prey species of full range size classes. (Attack rates (a) are measured in units of surface area of habitat for a standard time ($^{-1}$). Handling times T_h) are in hours (h). The probabilities are generated from the Correlation Co-efficiency).

Predator Instar	Mean total body length (± S. D. in mm.)	Prey Size Class							
		Aedes larva				Culicine larva			
	n = 25	1 2.81±.05mm	2 3.98±.01mm	3 5.23±.01mm	4 6.74±.06mm	1 1.25±.02mm	2 3.11±.01mm	3 4.24±.04mm	4 6.34±.06mm
I	4.27 ± .02	$a = 0.4265\ h^{-1}$ $T_h = 0.0354$ h $P < 0.1$	$a = 0.7335$ $T_h = 0.0489$ $P < 0.1$	$a = 0.5822$ $T_h = 0.0033$ $P < 0.1$	$a = 0.0036$ $T_h = 0.408$ $P < 0.1$	$a = 0.4862$ $T_h = 0.0985$ $P < 0.2$	$a = 0.1063$ $T_h = 0.1665$ $P < 0.1$	$a = 4.0451$ $T_h = 0.0027$ $P < 0.1$	$a = 0.6347$ $T_h = 0.0837$ < 0.1
II	6.51 ± .11	$a = 1.0441$ $T_h = 0.0122$ $P < 0.1$	$a = 5.6034$ $T_h = 0.0684$ $P < 0.1$	$a = 2.7756$ $T_h = 0.0442$ $P < 0.1$	$a = 0.6596$ $T_h = 0.0199$ $P < 0.01$	$a = 0.5286$ $T_h = 0.0617$ $P < 0.05$	$a = 1.3557$ $T_h = 0.0695$ $P < 0.1$	$a = 1.8913$ $T_h = 0.0717$ $P < 0.1$	$a = 1.9761$ $T_h = 0.0983$ $P < 0.2$
III	7.61 ± .72	$a = 1.3705$ $T_h = 0.0406$ $P < 0.1$	$a = 0.1032$ $T_h = 0.2364$ $P < 0.1$	$a = 2.1900$ $T_h = 0.0385$ $P < 0.1$	$a = 2.0547$ $T_h = 0.0598$ $P < 0.1$	$a = 1.3868$ $T_h = 0.0456$ $P < 0.1$	$a = 1.8334$ $T_h = 0.0533$ $P < 0.1$	$a = 2.3151$ $T_h = 0.1177$ $P < 0.1$	$a = 1.1323$ $T_h = 0.0933$ $P < 0.1$
IV	9.82 ± .31	$a = 1.1845$ $T_h = 0.016$ $P < 0.1$	$a = 2.3540$ $T_h = 0.0323$ $P < 0.1$	$a = 0.6699$ $T_h = 0.0103$ $P < 0.1$	$a = 0.7429$ $T_h = 0.0217$ $P < 0.1$	$a = 1.1274$ $T_h = 0.0369$ $P < 0.1$	$a = 5.0337$ $T_h = 0.0881$ $P < 0.1$	$a = 1.9340$ $T_h = 0.0627$ $P < 0.1$	$a = 1.9782$ $T_h = 0.0544$ $P < 0.1$
V	13.04 ± .69	$a = 1.2354$ $T_h = 0.0317$ $P < 0.1$	$a = 0.1364$ $Th = 0.1848$ $P < 0.1$	$a = 0.9222$ $T_h = 0.0586$ $P < 0.2$	$a = 1.4093$ $T_h = 0.0452$ $P < 0.1$	$a = 1.4866$ $T_b = 0.0393$ $P < 0.1$	$a = 1.0005$ $T_h = 0.0084$ $P < 0.1$	$a = 0.1675$ $T_h = 0.0054$ $P < 0.001$	$a = 1.1873$ $T_h = 0.0252$ $P < 0.2$

explaining the effective predatory behaviour. The attack rate is more when the smaller predator instars (I, II) are exposed to medium sized prey classes (2nd and 3rd) of both prey species. The larger predator instars (IV) exhibited higher attack rate towards smaller prey species (1st and 2nd). On the other hand, the over all handling time is comparatively low, when 1st prey classes *(Aedes)* was exposed ot I and II instars, 2nd prey size class *(Culex)* exposed to I instar and 2nd and 3rd prey size classes of *Culex* exposed to I and V instars.

As the predator increases in size, its attack rate on larvae of *Aedes* and *Culex* of different sizes varied in a complex way. When all predator instars were provided with *Aedes* larvae as food, it was expected that the attack rate would increase with increasing predator size and decreasing prey size. Predator instar I showed typical functional response on all prey groups. Predator instars II and IV showed a high attack rate and handling time. But in instar II, a and T_h first rise and then fall as one goes from prey size classes 1 to 4.

Significant variation in the values of a and T_h were observed when larvae of *Culex* were attacked. It was expected that the functional response of all predator instars tend to be high as in *Aedes*. Interestingly, variation is observed in the values of a and T_h for changing prey size classes of both species, when the instar II was exposed to all size classes of both prey species, the T_h seems to be unaltered.

Selective predation

When the experiments were conducted in a comparable condition, it was expected that there could be minimum variation in the values of a and T_h, which could be related with variation in sizes of the larvae. Changes in the values of a and T_h to a significant level could be probably related with the behaviour of the predator and prey and the palatability of the prey.

The looping movement of *Culex* and sluggish movement of *Aedes* may be pointed out for the unexpected changes in attack rate. However, the handling time reflects on the eatability (when a prey is successfully fed) of the predator to the changing prey species.

DISCUSSION

The prey death rate is higher with larger instars of the predator than with smaller instars. In general, *Aedes*, the larger prey species, is attacked maximum by all stages of predator instars. This preference indicates the existence of food selection among the water bugs, a feature not uncommon among other insects (BLUMBERG & SWIRSKI, 1974).

In addition to prey death rate, the functional response involving predation also includes attack rate and handling time wherein the attack rate theoretically increases as handling time decreases (HASSELL *et al.*, 1976). Such a relationship between attack rate and handling time exists, in general, among instars of *Diplonychus*, when exposed to *Aedes* or *Culex* larvae. However, the relationship is altered in certain predator stages. Such an alteration between a and T_h is not uncommon in insects (WRATTEN, 1973; EVANS, 1973). The attack rate increases with increasing handling time while preying on 2nd and 3rd size classes of *Culex* and *Aedes*. However, this relationship is pronounced more with *Culex* than with *Aedes*. This could

be interpreted as a complex type II functional response wherein the sub-components of the handling time (time takan to subdue, eat and digest each prey) are prolonged. This fairly complex functional response reflects on the occurrence of the successful killing and eating in the intermediate stages of the predator (II and III). This complexity in the response surfaces was attributed to the intermediate size of prey or predator (HASSELL *et al.*, 1976) that has been observed in the present study.

The increasing handling time to the decreasing attack rate results in the unsuccessful attack of the predator on the prey, which is not uncommon when the maximal and minimal stages of the predator attacked full size range classes of *Aedes* and not *Culex*. Similarly, the increase in the attack rate to the increasing handling time is observed in the intermediary predator stages when exposed to *Culex* rather than *Aedes*. However, the general concept is justified in *Diplonychus*-mosquito larvae system which specifically expresses the complexity only when exposed to full range size clases of *Culex*. The more important is as the predator grows larger, attack rate is proportionately increased and gradually decreased during culmination. Variation is brought about in the handling time with the increasing tendency to the increasing attack rate while attacking *Culex* and decreasing trend on *Aedes*. As a result, the involvement of more than one prey species results in the variation of the components of functional response which are associated with the predatory behaviour besides the qualtiy of prey (VENKATESAN & RAO, 1979). Hence, the quality of pray also has a direct influence on the pattern of variation of the functional response surfaces (HOLLING *et al.*, 1976). The increasing attack rate could be interpreted in terms of its subcomponents and one of the sub-components is the eatability. The *Culex* predated instars showed the corresponding increase of attack rate and handling time that suggests the involvement of time factor in eating and digesting the prey, which may not be prolonged when merely attacked and killed as emphasized in the *Aedes* predated forms.

The present argument is whether what is preyed upon is actually eaten and assimilated by the predator or not. THOMPSON (1951) has argued that all predaceous insects do not often eat the prey and quality and palatability of the prey govern the eatability and not the quantity of the prey. The present investigation emphasizes that the importance of eating could be accompanied with the increasing handling time and the quality of the prey. This finding probably suggests that the behaviour of the predator could be concentrated on the selection of the prey and eatability operates secondarily depending upon the efficiency and the nature of the prey.

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OPTIMISING THE DOSE AND SPRAY INTERVAL OF SYNTHETIC PYRETHROIDS AGAINST BRINJAL FRUIT AND SHOOT BORER, *LEUCINODES ORBONALIS*

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Efficacy of fenvalerate, permethrin and cypermethrin was tested against brinjal fruit borer, L. orbonalis using three different dosages at three spray intervals. All the synthetic pyrethroids were highly effective at their reduced dosages and also at increased spray intervals. The interactions between dosages and time of applications were highly significant, Maximum net income was obtained in the case of cypermethrin 30 g ai/ha at 15 days interval but the benefit cost ratio was maximum (11.88) in the case of cypermethrin 15 g ai/ha at 20 days interval.

(Key words: synthetic pyrethroids, dose time interaction, economics, *Leuoinodes orbonalis)*

INTRODUCTION

VOON & CHUNG (1978) reported the efficacy of synthetic pyrethroids for the first time against *Leucinodes orbonalis* Guen infesting brinjal. Several reports appeared since then comfirming the effectiveness of synthetic pyrethroids against this pest (KUPPUSAMY & BALASUBRAMANIAN, 1980: NIMBALKAR & AJRI, 1981: ABUDL ALLAM *et al.*, 1982: AZEEZ BASHA *et al.*, 1982) but no efforts have been made to find out the minimum effective dose and also the standard interval between two applications for various synthetic pyrethroids. The information is essential as they are high priced chemicals and also keeping in view their highly toxic effect against non-target animals. The present experiment was, therefore planned to find out the optimum dose and standard spray interval of three different synthetic pyrethroids against brinjal shoot and fruit borer *L. orbonalis*.

MATERIALS AND METHODS

A field experiment was conducted in Split Plot Design using brinjal variety '*Pusa purple long*' during August–December, 1982. Fenvalerate, permethrin and cypermethrin were tested in three dosages (75, 50 and 30 g ai/ha of fenvalerate and permethrin; 30, 22.5 and 15 g ai ha of cypermethrin) at three spray intervals (15, 20 and 25 days). The insecticide and dose combinations were kept as main plot and intervals of application as sub plot. All the treatments were replicated thrice keeping individual plot size 5m × 3m. First spray was given 50 days after transplanting and subsequently at various intervals depending on treatments. Data on number of healthy and damaged fruits at each picking were recorded and pooled for analysis. The economics of different treatments was worked out on the basis of prevailing market rates of insecticides, labour charges and produce.

RESULTS AND DISCUSSION

Table 1 indicates that all the three dosages of different synthetic pyrethroids were significantly superior over control. All the tested dosages were also significantly different from each others

with higher dose resulting in minimum borer incidence in all the cases. Similarly, different spray intervals were also significantly different from each other and in all cases 15 days interval resulted in minimum borer incidence as compared

TABLE 1. Effect of different dosages and spray interval of synthetic pyrethroids on the incidence of *Leucinodes orbonalis* Guen.

dose** (main plot)	mean % infestation*			application interval (sub plot)	mean % infestation*		
	fenvalerate	permethrin	cypermethrin		fenvalerate	permethrin	cypermethrin
D_1	13.64 (75)	14.60 (75)	12.42 (30)	15	18.69	18.83	18.65
D_2	17.36 (50)	16.83 (50)	17.30 (22.5)	20	22.25	21.83	22.24
D_3	20.00 (30)	19.82 (30)	20.81 (15)	25	25.34	25.80	25.40
D_4	37.35 (0)	37.35 (0)	35.35 (0)				
SEM	0.35	0.52	0.40		0.31	0.26	0.35
CD at 5%	1.86	1.54	2.16		0.92	0.77	1.04

* Sin^{-1} $0.5\sqrt{x}$ values. ** Figures in parantheses are the actual dosages in g ai/ha.

TABLE 2. Interaction means (% infestation^{+}) between dosages and application interval of different synthetic pyrethroids applied against *L. orbonalis* Guen.

insecticide	dosage ai/ha (g)	application interval (days) 15	20	25	SEM	CD 5% **
fenvalerate	75	9.374	12.273^{a}	19.272^{bc}	0.871	1.831
	50	12.705^{a}	18.296^{b}	21.081^{c}		
	30	15.320	21.071^{c}	23.629		
	0	37.359	37.359	37.359		
		SEM	1.159			
		CD 5%*	2.343			
permethrin	75	9.920	13.687^{c}	20.190^{b}	0.728	1.544
	50	11.597^{c}	17.035^{a}	21.870		
	30	16.450^{a}	19.231^{b}	23.788		
	0	37.359	37.359	37.359		
		SEM	1.239			
		CD 5%*	2.603			
cypemethrin	30	6.811	11.212^{a}	19.225^{b}	0.985	2.070
	22.5	11.907^{a}	19.374^{b}	22.127^{c}		
	15	18.519^{b}	21.012^{bc}	22.900^{c}		
	0	37.359	37.359	37.359		
		SEM	1.337			
		CD 5%*	2.809			

* Difference between two main plot mean at same different levels of sub-plot.
** Same sub-plot among different main plot. + Sin^{-1} $0.5\sqrt{x}$ values.
Interaction means followed by same alphabet are not significantly different.

to 20 and 25 days intarvals. Interaction between dosages and spray intervals for different insecticides were highly significant (Table 2). In the case of fenvalerate, application of 50 g ai/ha at 15 days interval was significantly at par with 75 g ai/ha at 20 days interval resulting in respectively 12.705 and 12.273 per cent mean infestation. Similarly, fenvalerate 50 g ai/ha at 20 days interval resulted in statistically similar mean incidence to that of 75 g ai/ha at 25 days interval. Fenvavlerate @ 30 g ai/ha at 20 days was found to be at par with 50 g ai/ha at 25 days interval. In the case of permethrin, no significant difference was observed between the application of 30 g ai/ha at 15 days interval and 50 g ai/ha at 20 days interval. Similarly, the mean percentage infestation was statistically similar in the case of 30 g ai/ha at 10 days interval and 75 g ai/ha 25 days interval. Application of permethrin @ 75 g ai/ha at 20 days was found to be at par to that of 50 g ai/ha at 15 days interval in reducing the borer incidence. Cypermethrin @ 15 g ai/ha at 20 days and 25 days interval resulted in no significant difference in the mean percentage infestation. Interaction mean for cypermethrin 22.5 g ai/ha at 15 days (11.907) was statistically not significant with that of 30 g ai/ha at 20 days interval (11.212). Similarly, the mean infestation in cypermeterin 15 g ai/ha at 15 days interval was satistically at par to that of 15 g ai/ha 20 days, 22.5 g ai/ha at 20 days and also to that of 30 g ai/ha at 25 days interval. Cypermethrin @ 15 g ai/ha at 20 days was on par to cypermethrin 22.5 g ai/ha at 25 days and also to that of cypermethrin 15 g ai/ha at 25 days interval.

The results summarised in Table 3 indicate that maximum net income was obtained in the case of cypermethrin 30 g ai/ha at 15 days interval followed by permethrin 75 g ai/ha at 20 days and permethrin 75 g ai/ha at 15 days interval. The benefit/cost ratio was, however, maximum (11.88) in the case of cypermethrin 15 g ai/ha at 20 days interval followed by permethrin 30 g ai/ha at 20 days (11.60) and cypermethrin 15 g ai/ha at 15 days (11.22) interval.

Thus, it can be concluded that fenvalerate, permethrin and cypermethrin remain highly effective against brinjal fruit borer when applied in lower dosage and also at increased application interval. Higher benefit/cost ratio was obtained at lowest dose of cypermethrin (15 g ai/ha) followed by lowest dose of permethrin (30 g ai/ha) when applied at 20 days interval. Present finding of the effectiveness of synthetic pyrethroids up to 20 days is supported by NIMBALKAR & AJRI (1981) who found that cypermethrin (0.011%), fenvalerate (0.015%) and permethrin (0.015%) when applied at 21 days interval prevented the attack of brinjal fruit borer very effectivelly. According to AZEEZ BASHA *et al* (1982), fenvalerate, permethrin and cypermethrin applied @ 50 g ai/ha each at fortnightly interval against brinjal fruit borer resulted 25.87, 34.44 and 24.98 per cent infestation respectively as against 70.96 per cent in control. KUPPASWAMY & BALASUBRAMANIAN (1980) found cypermethrin, fehvalerate and permethrin highly effective against brinjal borer each at 0.005 per cent concentration. Fenvalerate (0.005 and 0.01 percent) applied at fortnightly interval was found highly effective against brinjal fruit borer by ABDUL ALLAM *et al.* (1982). No report, however is available to compare the results on efficacy of reduced dosages at increased application interval and also on the

TABLE 3. Economics of different treatments used for the control of *L. orbonalis* Guen.

insecticide	dose ai/ha (g)	application interval (days)	net income (thousand Rs/ha)	benefit/cost ration
fenvalerate (sumicidin)	75	15	4.311	5.75
		20	4.225	7.23
		25	3.400	6.02
	50	15	3.489	7.07
		20	3.465	9.04
		25	2.433	6.64
	30	15	3.302	9.06
		20	2.205	8.17
		25	2.028	7.60
permethrin (volrhopermethrin)	75	15	4.412	6.13
		20	4.579	8.36
		25	3.451	6.35
	50	15	3.629	7.62
		20	2.161	6.94
		25	2.561	6.94
	30	15	3.384	9.63
		20	3.115	11.60
		25	2.602	9.85
cypermethrin (ripcord)	30	15	4.756	9.43
		20	3.184	8.52
		25	3.121	8.37
	22.5	15	3.332	8.51
		20	3.140	10.44
		25	1.619	5.99
	15	15	3.294	11.22
		20	2.631	11.88
		25	2.447	11.12

1. Treatment cost includes the cost of insecticide (sumicidin: Rs. 550/lit.; volrhopermethrin: Rs. 520/lit; ripcord: Rs. 404/lit) plus labour charger @ Rs. 10 per man days/spray/ha. 2. Cost of brinjal Rs. 120.0.

benefit/cost ratio of different treatments.

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DIFFERENTIAL RESPONSE OF AMERICAN COCKROACH *PERIPLANETA AMERICANA* L. TO CHLORINATED HYDROCARBON INSECTICIDES WHEN ACCLIMATIZED TO DIFFERENT TEMPERATURES

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Toxicity of endrin, toxophene and heptachlor was enhanced when cockroaches acclimatized to 33°C and 15°C were subjected to a post-treatment temperature of 28°C as compared to cockroaches maintained and tested at ambient temperature (28°C). This investigation also reports that acclimatized cockroaches when tested at their respective acclimatization temperatures were more resistant to the insecticides than those maintained and tested at 28°C. The degree of susceptibility towards each insecticide and the relative sex difference fluctuated with the acclimatization temperatures. In view of these interesting findings it is concluded that acclimatization increases the tolerance of insects to insecticides at their respective acclimatization temperatures. Tha possible mechanisms for this remarkable phenomenon is discussed.

(Key words: differential response, *Periplaneta americana*, chlorinated hydrocarbons, different temperature)

INTRODUCTION

Attempts have been made by different investigators to study the effect of intrinsic factors on the toxicity of insecticides (BUSVINE, 1971). Among these factors temperature plays an important role, with the result that some insecticides have negative temperature coefficient and some positive temparature coefficient. Among chlorinated hydrocarbons DDT and from plant products pyrethrins have negative temparature coefficient, whereas other chlorinated hydrocorbons like cyclodiene compounds and organophosphorus compounds have positive temperature coefficient (BUSVINE 1971).

GUTHRIE (1950) attempted to establish the effect of acclimatization on the toxicity of certain organic insecticides. He found that DDT, pyrethrum and lindane were more toxic while reverse was true with aldrin and dieldrin. Similarly, RAI (1967a, b) reported the relative toxicity of several insecticides to *Locusta migratoria*. However, he found that there were no significant differences in the toxicity of insecticides at different acclimatization temperatures. MUNSON (1953) demonstrated that nymphs of American cockroach kept at 17°C for 2 weeks were more resistant to DDT than those kept at 34°C. But, cockroaches kept longer than two weeks at 17°C were no longer resistant. These results evidently suggest that the duration for which the insects are held at a particular temperature, affects the toxicity of insecticides.

In the past little work has been reported on post-treatment temperature and the toxicity of insecticides and very little information is available on the toxicity of insecticides to insects acclimatized to different temperatures. Therefore, work was undertaken to study the effect of such parameters on the toxicity of chlorinated hydrocarbon insecticides to American cockroach *Periplaneta americana* L.

MATERIALS AND METHODS

Adult cockroaches, *Periplaneta americana* L. aged 20—40 days were used in all experiments and were obtained from laboratory stock culture maintained for several generations under standard conditions of temperature 28 ± 1°C and 75% RH. Humidity was kept constant throughout the experimental period. Cotton pads soaked in water and buiscuit powder and potato peels were provided every day. In all the experiments cockroaches were weighed individually to calculate the dosage administered to each insect at 5 µg per gram body weight of the insect.

Acclimatization of cockroaches

Two different temperatures were carefully selected for acclimatization of cockroaches: (i) high temperature 33°C; and (ii) low temperature 15°C since above and below these temperatures, natural mortality of cockroaches was observed. For the purpose of acclimatization adult cockroaches, about 50 in each cage of (mesh 40) 10″ × 7″, were taken, and several such cages were placed in thermostatically controlled cabins maintained at high (33°C) and low (15°C) temperatures. During the period of acclimatization the cockroaches were given the same type of food and water as mentioned above, as the normal counterparts maintained at 23°C (ambient temperature). As it has been demonstrated by KAISER JAMIL (1984) that the cockroaches take about 20—25 days at higher temperature (33°C) and 37—40 days at lower temperature (15°C) for acclimatization, insects were drawn from the acclimatization cabins for toxicity testing between 40 and 45 days of acclimatization at the two temperatures. Cockroaches from each of the three temperatures, 33°C, 28°C, 15°C were grouped in batches of 10 each and at least three such batches were used for testing each concentration of the insecticide.

Insecticides:

The insecticides used were of the following purity, grade and source;

insecticide	grades & purity	sources
1. Endrin	Tech. grade, 91%	Shell & Company USA
2. Toxaphene	Tech. grade, chlorine content (67-69%)	Hercules Powder Co., Wilington, USA.
3. Heptachlor	Tech. grade	Mysore Insecticide Co.

Preparation of insecticide solutions and their mode of application:

Insecticidal compounds were weighed and dissolved in acetone (W/V). Stock solutions of known concentrations were prepared and stored in a refrigerator. From the stock solution different concentrations of compounds were prepared by further dilution with acetone, whenever needed. Insects were sexed and the predetermined dosage of the test solution was administered into the haemocoel using Agla micrometer syringe.

The treated insects were held for 48 hr for mortality records at their respective acclimatization temperatures (33°C and 15°C) as well as at room temperature (28°C) in order to study the effect of post-treatment temperatures on the toxicity of insecticides to insects acclimatized at different temperatures. The results obtained with insecticides were subjected to probit/log concentration transformation on IBM computer 1620 model II. The LD50 and LD90 data thus collected and as described by FINNEY (1952) are shown in the Tables.

RESULTS AND DISCUSSION

From the results shown in (Tables 1, 2 and 3) it is clear that the toxicity of insecticides to cockroaches acclimatized at warm and cool temperatures varies with the acclimatization temperatures. It was found that the toxicity

TABLE 1. Toxicity of endrin to adult male (M) and female (F) cockroaches tested and acclimatized at different temperatures.

Acclimatization temperatures °C	Test temp °C	Sex of the insect	Regression equation	Heterogeneity	LC_{50}	Fiducial limits	Relative sex difference	LC_{90}	Fiducial limits	Relative sex difference
28	28	M	Y= .1172+2.7519×	X^2=1.781 (3)	0.0594 ± 0.0010	0.0716 0.0493	1.80	0.1736 ± 0.0010	0.2273 0.1324	2.10
28	28	F	Y= −.0896+2.4847×	X^2=7.733 (3)	0.1092 ± 0.0010	0.1368 0.0913		0.3659 ± 0.0010	0.5014 ± 0.2671	
33	28	M	Y= −.1093+3.0161×	X^2=2.827 (2)	0.0501 ± 0.0010	0.0562 0.0497	1.00	0.1313 ± 0.0010	0.1748 0.0987	1.00
33	28	F	Y= −.1515+3.0298×	X^2=2.764 (2)	0.0501 ± 0.0010	0.0601 0.0417		0.1326 ± 0.0010	0.1766 0.0996	
33	33	M	Y= −.9768+2.7030×	X^2=6.871 (4)	0.1626 ± 0.0010	0.1920 0.1377	1.09	0.4339 ± 0.0010	0.6288 0.3639	0.96
33	33	F	Y= −.9169+3.0705×	X^2=6.855 (3)	0.1788 ± 0.0010	0.2124 0.1506		0.4671 ± 0.0010	0.5994 0.3641	
15	28	M	Y= −.0893+3.1441×	X^2=2.731 (2)	0.0415 ± 0.0010	0.0499 0.0345	1.78	0.1060 ± 0.0010	0.5077 0.0820	1.99
15	28	F	Y= −.2083+2.7894×	X^2=5.488 (3)	0.0736 ± 0.0010	0.0879 0.0615		0.2118 ± 0.0010	0.2789 0.1609	
15	15	M	Y= −.0900+2.3349×	X^2=4.633 (3)	0.1293 ± 0.0010	0.1584 0.1054	1.64	0.4596 ± 0.0010	0.6580 0.3260	1.20
15	15	F	Y= −2.1625+3.0678×	X^2=7.755 (3)	0.2122 ± 0.0010	0.2487 0.1820		0.5546 ± 0.0010	0.7264 0.4233	

TABLE 2. Toxicity of toxaphene to adult male (M) and female (F) cockroaches *Periplaneta americana* L., tested and acclimatized at different temperatures.

Acclimatization temperatures °C	Test temp °C	Sex of the insect	Regression equation	Heterogeneity	LC_{50}	Fiducial limits	Relative sex difference	LC_{90}	Fiducial limits	Relative sex difference
28	28	M	$Y = -5.1120 + 3.3676 \times$	$X^2 = 3.212$ (2)	1.0060 ± 0.0010	1.0090 0.8650	1.53	2.4140 ± 0.0010	3.1900 1.8210	1.22
28	28	F	$Y = -9.2973 + 4.4873 \times$	$X^2 = 2.478$ (3)	1.5350 ± 0.0010	1.7180 1.3720		2.9610 ± 0.0010	3.4790 2.5050	
33	28	M	$Y = -7.6866 + 4.3985 \times$	$X^2 = 4.362$ (3)	0.7660 ± 0.0010	0.8590 0.6829	1.00	1.5080 ± 0.0010	1.5170 1.4990	1.00
33	28	F	$Y = -8.4910 + 4.6472 \times$	$X^2 = 2.965$ (3)	0.7660 ± 0.0010	0.7681 0.7637		1.5080 ± 0.0010	1.7770 1.2790	
33	33	M	$Y = -16.7921 + 6.1289 \times$	$X^2 = 4.233$ (3)	3.5940 ± 0.0010	3.8860 3.3240	1.03	5.8130 ± 0.0010	6.5800 5.1370	1.06
33	33	F	$Y = -15.8447 + 5.8352 \times$	$X^2 = 4.359$ (3)	3.7350 ± 0.0010	4.0480 3.4440		6.1870 ± 0.0010	7.1340 5.3680	
15	28	M	$Y = -10.1085 + 5.3524 \times$	$X^2 = 2.589$ (2)	0.6648 ± 0.0010	0.7406 0.5968	1.35	1.0140 ± 0.0010	1.3520 0.9833	1.57
15	28	F	$Y = -10.2990 + 5.1759 \times$	$X^2 = 3.840$ (3)	0.9010 ± 0.0010	0.9926 0.8265		1.5960 ± 0.0010	1.0590 1.3700	
15	15	M	$Y = -15.7912 + 5.8492 \times$	$X^2 = 4.729$ (3)	3.8430 ± 0.0010	4.1630 3.5470	1.20	6.3960 ± 0.0010	7.3790 5.5460	1.03
15	15	F	$Y = -25.1685 + 8.2294 \times$	$X^2 = 5.122$ (3)	4.6340 ± 0.0010	4.9140 4.3600		6.6280 ± 0.0010	7.2710 6.0430	

TABLE 3. Toxicity of heptachlor to adult male (M) and female (F) cockroaches *Periplaneta americana* L., tested and acclimatized at different temperatures.

Acclimatization temperatures °C	Test temp °C	Sex of the insect	Regression equation	Heterogeneity	LC_{50}	Fiducial limits	Relative sex difference	LC_{90}	Fiducial limits	Relative sex difference
28	28	M	$Y=-1.6443+3.0922\times$	$X^2=8.961$ (5)	0.1360 ± 0.0010	0.1610 0.1231	1.00	0.4355 ± 0.0010	0.4536 0.2941	1.00
28	28	F	$Y=-.304+2.5331\times$	$X^2=10.349$ (5)	0.1360 ± 0.0010	0.1598 0.1158		0.4355 ± 0.0010	0.5798 0.3272	
33	28	M	$Y=-1.1321+3.0282\times$	$X^2=9.483$ (4)	0.1214 ± 0.0010	0.1440 0.1024	1.01	0.3215 ± 0.0010	0.4284 0.2412	0.98
33	28	F	$Y=-1.9531+3.2942\times$	$X^2=8.754$ (4)	0.1230 ± 0.0010	0.1508 0.1104		0.3156 ± 0.0010	0.4105 0.2429	
33	33	M	$Y=-13.1550+7.2269\times$	$X^2=8.439$ (5)	0.3252 ± 0.0010	0.3437 0.3077	1.03	0.4889 ± 0.0010	0.5389 0.4435	1.04
33	33	F	$Y=-12.4922+6.9310\times$	$X^2=4.809$ (5)	0.3339 ± 0.0010	0.3534 0.3156		0.5110 ± 0.0010	0.5671 0.4604	
15	28	M	$Y=-3.6189+4.0983\times$	$X^2=6.521$ (3)	0.1268 ± 0.0010	0.1450 0.1109	1.19	0.2602 ± 0.0010	0.3241 0.2089	0.95
15	28	F	$Y=-6.9590+5.4853\times$	$X^2=2.954$ (2)	0.1514 ± 0.0010	0.1665 0.1376		0.2591 ± 0.0010	0.3065 0.2191	
15	15	M	$Y=-17.5877+9.070\times$	$X^2=3.634$ (4)	0.3091 ± 0.0010	0.3261 0.2931	0.95	0.4270 ± 0.0010	0.4605 0.3976	1.00
15	15	F	$Y=-14.2898+7.8062\times$	$X^2=2.232$ (5)	0.2958 ± 0.0010	0.3125 0.2710		0.4270 ± 0.0010	0.4284 0.4273	

of endrin, toxaphene and heptachlor, to cockroaches acclimatized at 33°C and 15°C, was considerably more when subjected to a post-treatment temperature of 28°C as compared to cockroaches maintained and tested at 28°C. However, degree of susceptibility in cockroaches towards each insecticide fluctuated with the acclimatization temperatures.

Cockroaches acclimatized and tested at a different temperature:

An interesting observation was that cockroaches acclimatized at 15°C were slightly more susceptible than those acclimatised at 33°C. The increase in susceptibility of cockroaches acclimatized at 33°C and 15°C when tested at 28°C may be due to the fact that insects are at once subjected to a new environment (ie., temperature) which is not natural to it. Further, it has already been pointed out earlier that after 25 days in insects acclimatized at 33°C and 40 days in insects acclimatized at 15°C a stabilised condition is reached with respect to physiological factors such as heart beat frequency, acetylcholine levels etc. (KAISER JAMIL 1984). Any change in its acclimatization temperature perhaps disturbs this delicate condition and makes them more prone to the insecticides. This view is further supported from the fact that cockroaches acclimatized at 15°C when tested at 28°C are encountered to a much greater change from their acclimatization temperature than those acclimatized at 33° and tested at 28°C and hence they are more susceptible than cockroaches acclimatized at 33°C.

Cockroaches acclimatized and tested at their acclimatization temperatures:

The toxicity results presented in Table 1 to 3 revealed a different pattern when warm and cool acclimatized cockroaches were subjected to their acclimatization temperatures (33°C and 15°C) after the treatment with insecticides. It was found that these acclimatized cockroaches were more resistant to the insedticides when tested at their respective acclimatization temperatures than those maintained and tested at 28°C. However the degree of resistance differed at the two acclimatization temperatures. It was found that cockroaches acclimatized and tested at 15°C were generally more resistant than those acclimatized and tested at a different temperature. It appears that cockroaches are fully adjusted to their new environment by suitable compensation in their physiological condition after acclimatization. Hence, they are able to withstand higher concentration of the insecticide which is otherwise lethal to insects maintained at room temperature. The above results thereby suggest that pre-conditioning of insects (ie., acclimatization) to a particular temperature for a sufficient length of time has a definite influence on the toxicity of insecticides.

Sex difference in toxicity:

The results of the toxicity of insecticides (Tables 1 to 3) also showed that the toxicity of each insecticide varies with the sex. Cockroaches maintained at room temperature (28°C) showed a sex difference in toxicity with endrin and toxaphene, where the males were found to be more susceptible to the insecticide than female insects. This is evident from the fact that lesser concentrations of the insecticide were required by males than female insects to produce the same percent mortality. It was also noticed that the relative sex difference in toxicity varied with the insecticide being more with endrin and toxaphene.

However, heptachlor did not show any sex difference in toxicity. Similar observations were made by MAC CUAIG (1966), BURNET (1962 a, b) and ISHII & SHERMAN (1965) who showed that the two sexes of the species *Locusta, Drosophila* and *Blatta* were equally susceptible to some insecticides. MUNSAN (1948) and LEWALLAN (1954) also reported that female cockroaches and houseflies were more susceptible than males to dichloroethyl ether and pyrethrum.

Most interesting results were observed on the relative sex difference in toxicity of insecticides to insects acclimatized at 33° and 15°C. It was found that the sex difference in toxicity of warm acclimatized insects was least when compared to the sex difference in toxicity observed in insects acclimatized at lower temperature. A most interesting finding is that cockroaches acclimatized at lower temperature (15°C) exhibited a greater sex difference in toxicity towards insecticides when tested at 28°C than at their acclimatization temperature. This may perhaps be due to the difference in degree of detoxification of the insecticide at different temperatures.

From the above studies on the toxicity of insecticides to acclimatized insects it may be concluded that among the important benefits conferred to insects by acclimatization to different temperatures is the unique capacity to resist the lethal concentration of the insecticides which are otherwise harmful to normal adult cockroaches maintained at ambient temperature (28°C). On the other hand, when cockroaches are subjected to temperatures other than their acclimatization temperature their capacity to tolerate the lethal dosage of the insecticide is decreased.

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INFLUENCE OF SPICE ESSENTIAL OIL ON THE LIFE HISTORY OF *LASIODERMA SERRICORNE* (F.)

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Lasioderma serricorne (F.) was reared on an artificial diet consisting of wheat flour and baker's yeast (10:1 by wt). It was found that incubation period of the eggs ranged from 10—19 days; the larval period was 10—18 days, pupal period 4—12 days and adult life span 16—19 days. The efficacy of essential oil of three spices viz., turmeric, black pepper and cardamom as such or dissolved in absolute ethyl alcohol, against infestation of respective spices by the insect, was evaluated. Essential oil coating inhibited cocoon formation and infestation of spices by this insect. It was found that the adults were more susceptible to treatment than the larvae. Mortality of the adults was noticed within 24 hr of treatment. All the three essential oils brought about 100% mortality of the treated adults at 0.1 ml per 10 g of the spice.

(Key words: Lasioderma serricorne, essential oil, life history, spices, infestation)

INTRODUCTION

Lasioderma serricorne (F.) (Coleoptera: Anobiidae) is a stored products pest attacking tobacco, spices and other agricultural produce (HOWE, 1957; BOSE *et al*, 1977; LE CATO, 1978). Major spices like cardamom *(Elettaria cardamomum* Linn), pepper *(Piper nigrum* Linn.), ginger *(Zingiber officinale)*, chilli *(Capsicum frutescens* Linn.), turmeric *Curcuma longa* Linn.) are susceptible to this beetle. Control of this insect by use of fumigants and organic insecticides has been reported (SAXENA & GOHAIN, 1976; VINCENT & LINDGREN, 1977; KAVADIA *et al*, 1978; MOSTAFA *et al*., 1980). However use of chemicals is hazardous because of likely residues on the agricultural produce. Many plant products, especially their oils are known to have a protective value against insect attack (SAXENA & SRIVASTAVA, 1973; KARASEV, 1976; MARIAPPAN & SAXENA, 1983). Hence it was decided to study if spice essential oil had any effect on this insect and spices could be protected from its attack.

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MATERIALS AND METHODS

Adults of *L. serricorne* (F.) were collected from infested turmeric in nearby market and the stock colony was reared in the laboratory in 500 ml conical flasks on an artificial diet under ambient conditions (30 ± 2°C and 78% RH). The artificial diet consisted of a variant reported by SINGH (1935) and was made up of a mixture of wheat flour and baker's yeast in the ratio 10:1 (w/w). 10 g of wheat flour was autoclaved for 15 min at a pressure of 15 lb/in² and was cooled and mixed with 1 g baker's yeast and moistened with approximately 0.1 ml of distilled water. Into 10 g of this diet in a 500 ml conical flask, 30 adults or larvae as the case may be, were released. Mouth of the conical flask was covered with fine mesh cloth.

For the study of the biology of the insect, thirty newly emerged adults were released in each 500 ml conical flask containing 10 g of the artificial diet. The incubation period, larval period, pupal period cocoon formation and adult life span were studied examining the flask daily. As the cocoons were constructed with the glass surface of the conical flask forming part of the cocoon wall, the development of the insect inside the cocoon could be easily observed. In order to study the emergence of the adult, the cocoons containing the adults were marked externally and numbered. Every day observation was made at 5.30 PM and 6.30 AM and the number of adults emerged from the cocoons was counted. To study the effect of spice essential oil on the insect, dried turmeric, pepper and cadamom were chosen. The essential oils of turmeric, pepper and cardamom used for coating was extracted in the laboratory from the respective spices by steam distillation method. Two sets of experiments were conducted. In the first set the essential oil was coated on respective spice. For this the oil was pipetted on the samples in conical flask and was then mixed using a rotary shaker for 5 min so that the spices got a uniform coating of the oil. Immediately after oil treatment, each was subsequently infested with 15 pairs of newly emerged adults and 20, one-day old larvae taken from stock-culture. Control was kept without any oil coating. All the tests were replicated four times. The second set of experiments were conducted by dissolving the essential oil in absolute alcohol and spraying on the spice. For this 0.01, 0.02, 0.03, 0.04, 0.05, 0.1, 0.2, 0.3, and 0.4 ml of essential oil was dissolved in 5 ml of absolute alcohol and each was then uniformly sprayed on 10 g spice. Then 10 pairs of newly emerged adults and 20, two-day old larvae were liberated on the spice. Controls were sprayed with absolute alcohol alone. All the tests were replicated 4 times.

RESULTS

Data on the life hisrory of the beetle is given in Table 1. Under laboratory conditions the insects survived well on the artificial diet and completed its life history for many generations continuously. Incubation period lasted for 10—19 days after which minute larvae were seen at the bottom of the flask. The larval period lasted for 10—18 days. Within this period the larvae underwent four moults before finally constructing cocoons, with the glass surface forming part of its wall. If the larva was disturbed it deserted the fully made cocoon and built a new one. This was also observed earlier by HOWE (1957). The larva became a pre-pupa inside the cocoon and after 2—4 days cast off the larval skin. The adult emerged from the cocoon after a period of 1—5 days and lived for 16—19 days.

TABLE 1. Duration of life stages of *Lasioderma serricorna* (F.).

Developmental stage	Duration (in days)	
	Range	M ± SD
Egg	10—19	15 ± 3.017
Larva	10—18	13 ± 2.965
Pupa	4—12	8 ± 2.966
Adult	16—19	17 ± 1.330
Egg to adult	42—45	44 ± 1.249

The cocoons are made of food and waste material cemented together by a secretion produced by the midgut (VAN EMBDEN, 1929). In *Lasioderma* 95% of the adults emerged during night (Table 2). The beetle actually took 42—45 days to complete its life cycle, though there was considerable individual variation in the duration of each stadium.

Tables 3—8 summarise the results of the studies on the effect of spice essential oil on insect infestation. Spice oil has got a negative effect on infestation and cocoon formation. In the

TABLE 2. Table showing time (day/night) of adult emergence of *Lasioderma serricorne* (F.)

Total No. adults in cocoons observed	No. of adults emerged during night/day					Percentage of adult emergence (night/day)
	1	2	3	4	5	
97	4 (0)	0 (1)	18 (0)	56 (0)	18 (0)	99 (1)
80	20 (1)	53 (1)	1 (1)	0 (1)	2 (0)	95 (5)
127	10 (0)	92 (2)	17 (3)	2 (1)	0 (0)	95 (5)
150	56 (3)	12 (1)	76 (1)	0 (1)	0 (0)	96 (4)
45	8 (0)	0 (1)	0 (0)	36 (0)	0 (0)	98 (2)
117	13 (0)	78 (2)	20 (2)	0 (2)	0 (0)	95 (5)
108	97 (0)	0 (1)	9 (0)	0 (1)	0 (0)	98 (2)
188	83 (3)	0 (1)	80 (4)	10 (1)	6 (0)	95 (5)
52	13 (0)	30 (1)	5 (1)	2 (0)	0 (0)	96 (4)
109	64 (0)	30 (2)	4 (0)	0 (0)	9 (0)	98 (2)

Numbers in parentheses are adults emerged during day.

studies involving the essential oil, it was found that mixing with alcohol did not make any difference. Infestation, survival and development were seen in the control kept by treating the spice with absolute alcohol. All essential oils have adverse effects on the insect at various treatment levels tried, though there is no difference as to whatever way the oil is applied direct or dissolved in alcohol. Cocoon formation is not seriously affected except at treatment levels of 0.3 ml/10 g or more for all the three spices, at which no cocoons were formed. Generally speaking mortality of the larvae increased more or less directly in proportion from 0.01 ml/10 g to 0.2 ml/10 g with increase in oil; with 0.3 ml/10 g mortality was 100%. Oils of turmeric, pepper and cardamom were effective in decreasing order, as 0.01 ml/10 g was LD_{50} for turmeric whereas, it was LD_{30} and LD_{25} only respectively for the other two.

Of all the dosages tried 0.3 ml/10 g prevented insect infestation and cocoon formation effectively. Dosages below that was insufficient for proper coating as noted by visual observation of the spice while with dosages above that, the insects became heavily coated with oil and most of them were sluggish in their movement. With adults, though very low treatment levels (from 0.01 to 0.05 ml/10 g) give rather uniformly low mortality, with doses from 0.1 ml/10 g or doses above that was effective to bring about 100% kill with all the three oils on respective spices, within ten days of treatment. With dosages between 0.1 ml to 0.3 ml 90% adult mortality took place within 2—3 days. All the oils at 0.3 ml/10 g onwards caused 100% adult- and larval death, prevented development and infestation of the beetle on the spices.

DISCUSSION

From the studies it is seen that insects started boring an uncoated sample of spice within 3—6 days while essential oil coating (at treatment level 0.3 ml/10 g of spice or above that) prevented larval and adult survival and development on the spices. However, 0.1 ml/10 g was enough to produce 100% mortality, in adults but 50% mortality in larvae. Larvae hence appear to be more resistant to the oil than the adults. A 40% weight loss of turmeric by tobacco beetle infestation has been reported by KAVADIA *et al.* (1978).

TABLE 3. Effect of application of turmeric essential oil on larval mortality, cocoon formation and infestation by *Lasioderma serricorne* (F.).

No. of larvae tested	Treatment levevel: ml oil/ 10 g turmeric	Method of application	Cocoons formed by day 1	No. of larvae surviving after 10 days	Mortality of larvae during 10 days (%)	Mortality of larvae during 11—20 days
80	0.01	Spraying	48	40	50	*Nil
80	0.02	Spraying	71	38	53	*Nil
80	0.03	Spraying	22	33	59	*Nil
80	0.04	Spraying	20	28	65	*Nil
80	0.05	Spraying	44	38	53	*Nil
		Coating	48	36	55	*Nil
80	0. 1	Spraying	42	36	55	*Nil
		Coating	40	32	60	*Nil
80	0. 2	Spraying	6	16	80	*Nil
		Coating	4	13	84	*Nil
80	0. 3	Spraying	Nil	Nil	100	—
		Coating	Nil	Nil	100	—
80	0. 4	Spraying	Nil	Nil	100	—
		Coating	Nil	Nil	100	—
80	Control (5 ml ethyl alcohol)	Spraying	32	76	5	*Nil

* All the larvae had formed cocoons and they survive; for spray, oil was dissolved in ethyl alcohol.

Formation of persistant toxic chlorohydrins in food stuffs by fumigation with ethylene oxide and with propylene oxide have been reported by WESLEY (1965). Heat treatment which is adopted as a control measure against insect infestation for may commodities is not applicable in the case of spices as it has been reported that heat treatment of spices results in serious loss of some of the volatile constituents (NATARAJAN & SHANKARACHARYA, 1972). Abnormal development and mortality due to oil treatment has already been reported by others using different oils (KARASEV, 1976; MARIAPPAN & SEXENA, 1983). Treatment of spices with essential oil seems to be a safe method as it does not have any toxic effect on the consumer or will not leave any toxic residues unlike many chemical control measures. In addition, coating of the spices with its own essential oil will add to the aroma of the spice and will not alter the flavour of the spice.

It is further interesting to note that these insects attack spices and infest them without getting themselves injured even though the mortality of both larvae and adult was observed. This is because the oil cells in the spices are not attacked by the insects while they feed only on starch cells in the spices. In cloves the oil cells are located on the periphery (MANGALAKUMARI, 1983) and

TABLE 4. Effect of cardamom essential oil on larval mortality, cocoon formation and infestation by *Lasioderma serricorne* larvae (F.).

No. of larvae tested	Treatment level: ml oil per 10 g cardamom	Method of application	Cocoons formed on day 1	No. of larvae surviving after 10 ds	Mortality of larvae during 10 ds (%)	Mortality of larvae during 11—20 ds
80	0.01	Spraying	24	60	25	*Nil
80	0.02	Spraying	8	58	28	*Nil
80	0.03	Spraying	10	48	40	*Nil
80	0.04	Spraying	8	44	45	*Nil
80	0.05	Spraying	26	38	53	*Nil
		Coating	24	32	60	*Nil
80	0.1	Spraying	25	38	53	*Nil
		Coating	32	36	55	*Nil
80	0.2	Spraying	22	22	73	*Nil
		Coating	8	16	80	*Nil
80	0.3	Spraying	Nil	Nil	100	—
		Coating	Nil	Nil	100	—
80	0.4	Spraying	Nil	Nil	100	—
		Coating	Nil	Nil	100	—
80	Control (5 ml ethyl alcohol)	Spraying	32	72	10	*Nil

* All the larvae had formed cocoons and they survived; for spray, oil was dissolved in ethyl alcohol.

TABLE 5. Effect of pepper essential oil on larval mortality, cocoon formation and infestation by *Lasioderma serricorne* (F.).

No. of larvae tested	Treatment level: ml oil per 10 g pepper	Method of application	Cocoons formed on day 1	No. of larvae surviving after 10 days	Mortality of larvae during 10 days (%)	Mortality of larvae during 11—20 days
80	0 01	Spraying	24	56	30	*Nil
80	0.02	Spraying	26	53	34	*Nil
80	0.03	Spraying	4	50	38	*Nil
80	0.04	Spraying	42	46	43	*Nil
80	0.05	Spraying	28	44	45	*Nil
		Coating	18	38	53	*Nil
80	0.1	Spraying	33	36	55	*Nil
		Coating	24	32	60	*Nil
80	0.2	Spraying	18	10	88	*Nil
		Coating	13	4	95	*Nil
80	0.3	Spraying	Nil	Nil	100	—
		Coating	Nil	Nil	100	—
80	0.4	Spraying	Nil	Nil	100	—
		Coating	Nil	Nil	100	—
80	Control (5 ml ethyl alcohol)	Spraying	48	76	5	*Nil

* All the larvae had formed cocoons and they survived; for spray, oil was dissolved in ethyl alcohol.

TABLE 6. Effect of turmeric essential oil on the mortality of *L. serricorne* (F).

No. of adults tested	Treatment level: ml of oil per 10 g turmeric	Mortality during 10 days of application		Mortality during 11–20 days of application	
		(No.)	(%)	(No.)	(%)
80	0 01	12	15	68	85
80	0.02	18	23	62	77
80	0.03	20	25	60	75
80	0.04	24	30	56	70
80	0.05	24	30	56	70
80	0.1	80	100	—	—
80	0.2	80	100	—	—
80	0.3	80	100	—	—
80	0.4	80	100	—	—
80	5 ml ethyl alcohol	12	15	68	85
80	No treatment	8	10	72	90

TABLE 7. Effect of cardamom essential oil on the mortality of *L. serricorne* (F.).

No. of adults tested	Treatment level: ml of oil per 10 g cardamom	Mortality during 10 days of application		Mortality during 11–20 days of application	
		(No.)	(%)	(No.)	(%)
80	0.01	20	25	60	75
80	0.02	24	30	56	70
80	0.03	23	29	57	71
80	0.04	24	30	56	70
80	0.05	30	38	50	62
80	0.1	80	100	—	—
80	0.2	80	100	—	—
80	0.3	80	100	—	—
80	0.4	80	100	—	—
80	5 ml ethyl alhocol	8	10	72	90
80	No treatment	4	5	76	95

TABLE 8. Effect of pepper essential oil on the martality of *L. serricorne* (F.).

No. of adults tested	Treatment level: ml of oil per 10 g pepper	Mortality during 10 days of application		Mortality during 11–20 days of application	
		(No.)	(%)	(No.)	(%)
80	0 01	20	25	60	75
80	0.02	21	26	59	74
80	0.03	22	28	58	72
80	0.04	24	30	56	70
80	0.05	28	35	52	65
80	0.1	80	100	—	—
80	0.2	80	100	—	—
80	0.3	80	100	—	—
80	0.4	80	100	—	—
80	5 ml ethyl alcohol	8	10	72	90
80	No. treatment	4	5	76	95

that may be the reason why this spice is not infested by tobacco beetle. Coating of spices with their own oil, thus acts as a safe method against insect attack, as it will neither cause toxicity; nor mask or alter the flavour.

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DISTRIBUTION OF VARIOUS CASTES IN DIFFERENT PARTS OF THE MOUND OF THE TERMITE, *ODONTOTERMES WALLONENSIS* WASMANN (ISOPTERA: TERMITIDAE)

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Population density (per 100 gm unit of fungus garden) of workers, soldiers and nymphs of the termite, *O. wallonensis* from the different parts of the mound viz., peripheral fungus garden, fungus garden around the royal chamber and from royal chamber itself, and the foraging population density (per 10^2 sq cm area) from the foraging covered runways on the eucalyptus trees were studied. Percentage of major workers in peripheral fungus garden and foraging covered runways was higher ($p<0.001$) compared to the other parts of the mound. Percentage of minor workers was more in the fungus garden around the royal chamber and in the royal chamber ($p<0.001$) than other parts of the mound. Very high percentage of soldiers was found in royal chamber ($p<0.001$). Nymphs were found concentrated in the fungus garden around royal chamber. It is evident from the above results that various castes of this species in different parts of the mound are distributed according to their functional behaviour. The duty of major workers is foraging, construction of the fungus garden and construction of the mound. The duty of minor workers is feeding the royal couple and young ones. Soldiers are meant to guard the foraging workers and the colony including royal couple in the royal chamber.

(Key words: Odontotermes wallonensis, caste distribution, mound, fungus-garden, royal chamber)

INTRODUCTION

Total population of various castes and their relative percentages in different species of termites have been studied by HOLDAWAY *et al.* (1935) in *Eutermes exitiosus*, GAY & GREAVES (1940) in *Coptotermis lacteus*, MUKERJEE & MITRA (1949) in *Odontotermes redemanni*, GUPTA (1953) in *O. obesus*, SEN SARMA & MISHRA (1969) in *Microcerotermes beesoni*, BASALINGAPPA (1972) in *O. assumuthi*, MALISSE *et al.* (1975) in *Odontotermes* sp., and AGARWAL (1976) in *O. obesus* and *O. microdentatus*. BLUM (1977) reported that the behaviour of individuals in a colony is often correlated with specific morphological or physiological characteristics which are often emphasized on the individuals within a caste. VEERANNA & BASALINGAPPA (1981) have studied the total population and relative percentages of foraging forms of *O. wallonensis* from the covered runways raised on the eucalyptus trees. Since there are no reports regarding the distribution of various castes in different parts of the mound next except by DARLINTON (1977) in *Macrotermes subhyalinus*, the present study is undertaken to unravel the same in the termite, *O. wallonensis*.

MATERIAL AND METHODS

Freshly collected royal chamber, fungus-garden (from peripheral region and around the royal chamber) from the mound nests in the field and the workers and soldiers from covered runways on eucalyptus trees were the materials for the present study. Population density of major and minor workers, and soldiers from the royal chamber was determined by 'whole count' method. Population size of various castes from different parts of the fungus garden was made according to the random sampling method (BASALINGAPPA, 1972), and the population of foraging forms from covered runways was made according to sampling unit of 10^2 sq cm area (VEERANNA & BASALINGAPPA, 1981). For comparison of various castes in different parts of the mound, Student 't' test is applied, the p value less than 0.05 is statistically significant.

RESULTS AND DISCUSSION

Population density of workers, soldiers and nymphs of the termite, *O. wallonensis* from foraging covered runways and from different parts of the mound viz., peripheral fungus garden, fungus garden around the royal chamber and royal chamber itself is given in Table 1.

Percentage of major workers in the peripheral fungus garden and foraging covered runways was higher ($p < 0.001$) than that of royal chamber and fungus garden around the royal chamber. High percentage of major workers in the above mentioned regions might be due to the foraging, construction and repairing of the mound. According to DARLINGTON (1977) in *Macrotermes subhyalinus*, the peripheral fungus garden consisted of mainly workers with minor workers slightly outnumbering the major workers, and the soldiers less than 5% of the total. In the trunk galleries, the percentage of major workers was more (70%) than the minor workers and soldiers.

In *O. wallonensis* the percentage of minor workers was high ($p < 0.001$) in the royal chamber when compared to other parts of the mound. This high percentage of minor workers might be for the porpose of feeding the royal couple and young ones and for transporting eggs from the royal chamber to fungus garden. High percentage of soldiers ($p < 0.001$) in the royal chamber was presumably for guarding the royal couple and to get food from minor workers. Though the royal pair all the time is found well protected in the royal chamber, the presence of high percentage of soldiers might be for facing the rare invasion (s) of predatory ants as occur in *O. assumuthi* (VEERANNA *et al.*, 1981). High percentage of nymphal population in the fungus garden around the royal chamber is reasonable because the thousands of eggs laid per day by the large physogastric queen were to be transported from royal chamber and stocked in masses for incubation. It is evident from the above results that various castes of this species in different parts of the mound are distributed according to their functional behaviour.

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TABLE 1. Distribution of workers, soldiers and nymphs in different parts of the mound nest and covered runways of the termite, *Odontotermes wallonensis* Wasmann.

Different parts of mound nest	Major workers	Minor workers	Soldiers	Nymphs	Total	Percentage of			
						Major workers	Minor workers	Soldiers	Nymphs
Peripheral fungus garden	597 ± 75	323 ± 47	115 ± 14	1183 ± 42	2218 ± 150	25.28 ± 1.31	13.11 ± 0.82	4.79 ± 0.23	56.82 ± 1.77
Fungus garden around the royal chamber	520 ± 13	669 ± 32	47 ± 1	10342 ± 486	11578 ± 498	4.65 ± 0.21	5.99 ± 0 38	0.42 ± 0.02	88.94 ± 0.57
Royal chamber	335 ± 53	1002 ± 95	476 ± 44	31 ± 2	1844 ± 175	18.16 ± 1.00	54.28 ± 1.61	25.78 ± 2.23	1.73 ± 0 40
Covered runways	287 ± 18	22 ± 2	15 ± 3	Nil	323 ± 19	87.93 ± 0.69	7.05 ± 0.50	5.02 ± 0.36	Nil

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BRIEF COMMUNICATION

FIRST REPORT ON THE OCCURRENCE OF *DASYCHIRA MENDOSA* (HUBNER) (LEPIDOPTERA: LYMANTRIIDAE) ON THE RUBBER PLANT GUAYULE (*PARTHENIUM ARGENTATUM*) IN TAMIL NADU

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(Received 9 August 1983)

Dasychira mendosa (Lepidoptera: Lymantriidae) is reported for the first time as a pest on the rubber plant guayule *(Parthenium argentatum)*.

(Key words: Dasychira mendosa, Lymantriid, rubber plant, pest, guayule, *Parthenium* argentatum)

Guayule is the Mexican common name for *Parthenium argentatum*, a member of sunflower family, Compositae. Of the 16 species of *Parthenium*, guayule is the only species known to produce rubber (BAIRD, 1975). It is a native of upland plateau in Mexico and Texas and is known to grow well in sub-tropical climate with low rainfall. It can live for 30-40 years under desert conditions where rainfall in less than 200 mm. The guayule plant has been grown successfully in semiarid climate of Madurai since 1981. However, in November, 1982 under All India Co-ordinated Project on introduction of Guayule, 10,000 seedlings were brought from National Botanical Institute, Lucknow (SRIVASTAVA & BHATIA, 1983) and were transplanted in about 3 acres at the Biomass Center, Madurai Kamaraj University.

According to earlier reports the wild guayule appears remarkably free of disease and insect pests, but under cultivation, the plants are susceptible to both (NAS, 1977). However, we have observed leaf damage in the guayule plantation trial plots. We collected eggs and caterpillars from the infected rubber plant after a careful and extensive survey of the plots. They were reared on the fresh leaves of guayule to adult stage in the laboratory and were identified at the Commonwealth Institute of Entomology as *Dasychira mendosa* (Hubner) (Lepidoptera: Lymantriidae).

A freshly hatched larva grew from 0.2 mg to a weight of 9 mg at the beginning of third instar. The weight attained a maximum of 501 mg at the final larval stage. First day pupa weighed about 300 mg and on completion of pupal period freshly emerged adult averaged to 210 mg. Feeding on rubber plant, *D. mendosa* passed through 6 larval instars in about 27 days to complete the feeding larval stage. It required 6 to 7 days to complete pupal period and the total life span of *D. mendosa* is about 34 days.

NAQVI & HANSON (1980) reported the occurrence of loopers like *Hyphantria cunea* and *Platynota stultana* in guayule

reared in California under greenhouse conditions. No other specific insect pests are reported on guayule so far. This is the first report on the occurrence of an insect pest on guayule in India Further work is under progress to estimate the bioenergetcis and population survey of the pest in the field and the damage to the rubber crop due to the insect.

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REPORTS AND NEW RECORDS

OCCURRENCE OF AN UNUSUAL TYPE OF FRENULUM IN *PYCNARMON CABERALIS* GUEN. (LEPIDOPTERA: PYRAUSTIDA)

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(Received 31 October 1983)

In the male *Pycnarmon caberalis* (Lepidoptera: Pyraustida), a long frenulum bearing a distal knob is reported.

(Key words: Pycnarmon caberalis, knobbed frenulum)

In higher Lepidoptera, the wing coupling apparatus is of the typical frenate type comprised of long spine-like frenulum on the hind wing and a retinaculum consisting of a tuft of stiffened hairs on the forewing. When the wings are spread, the frenulum passes beneath the postero-basal protion of the forewing and gets locked by the retinaculum (RICHARDS & DAVIES, 1977).

Most pyraustids possess long, spine-like frenulum which is usually single and stout in the male but slender and more than one in the female. In the male of *Pycnarmon caberalis*, a common pest of *Coleus* spp., the frenulum is very long and bears a distal rounded knob (Fig. 1). Knobbed frenulum has not been reported earlier in any other Lepidoptera. In the female, the frenulum is shorter and composed of two pointed spine-like processes, as usual. There is no difference in the retinaculum between the sexes except that it is denser in males. No such specialization was found in two other species of *Pycnarmon* viz., *P. maritalis* Wlk. and an undetermined species.

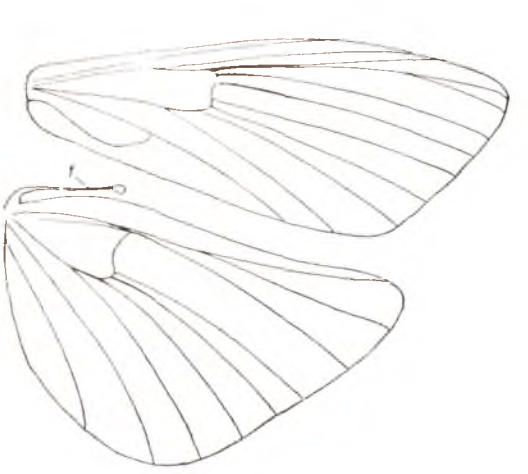

Fig. 1. Wings of *Pycnarmon caberalis* Guen. showing frenulum (f).

The significance of the wing coupling apparatus in the taxonomy of Crambinae and Pyraustinae, has recently been studied by SAUTER (1973) and he found it useful tor the segregation of these moths at the generic level.

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TAXONOMICAL AND BIOLOGICAL NOTES ON *ANCHON ULNIFORME* BUCKTON (HOMOPTERA: MEMBRACIDAE)

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(Received 25 September 1982)

Redescription of *Anchon ulniforme* Buckton with notes on its biology is presented.

(Key words: redescription, *Anchon ulniforme*, biological notes)

Anchon ulniforme was described by Buckton (1903) based on the material collected from Tenasserin (Burma). The orginal description is quite inadequate, as is the subsequent description by Distant (1908). In view of the fact that, as in many other species of membracids, intraspecific variations in addition to sexual dimorphism, has been noticed to occur in *Anchon ulniforme*, a detailed description is given in this paper based on long series of male and female specimens of this species collected from *Lablab purpureus* on which plant this species has been found to be a regular pest during the monsoon months, in Kerala State.

Female: General coloration dark reddish brown. Head vertical, vertex nearly thrice as wide as long, pale reddish brown, weakly convex transversely, finely punctate with short adpressed golden pilosity, upper margin shallowly arcuate, lower margin weakly sinuate and broadly rounded to frontoclypeus; eyes subglobate, mottled with light brown, ocelli closer to eyes than to each other and located well above the centro-ocular line; frontoclypeus sparsely longly pilose, slightly declivous, as wide as long, tip broadly rounded, frontoclypeal lobes fused to tip. Pronotum thickly pilose, slightly granulate, dark reddish on metopidium and basal stem of posterior process, with a cretaceously sericeous oblique line on each side commencing behind each suprahumeral horn and continued to the base of scutellum, finely punctate with short adpressed golden hairs, short reddish brown tubercles on and behind horns and on the basal stem of posterior process, each tubercle terminating in a bristle; metopidium vertical, nearly twice as wide at base as high, supraocular callosities concolorous with metopidium slightly divided, humeral angles prominent, subacute, posterior angles obtusely rounded; suprahumeral horns strongly tuberculate, thrice as long as the space between their bases, tricarinate, as seen from sides broad-based, directed obliquely upwards and forwards, their apices truncate and angulate posterioly, as seen from the front appearing narrower and gently recurved, the apices ampliate and subacute, viewed from above somewhat broad, strongly carinate behind middle, the apices ampliate and truncate, concave and lobate on posterior margins and strongly angulate posteriorly; posterior

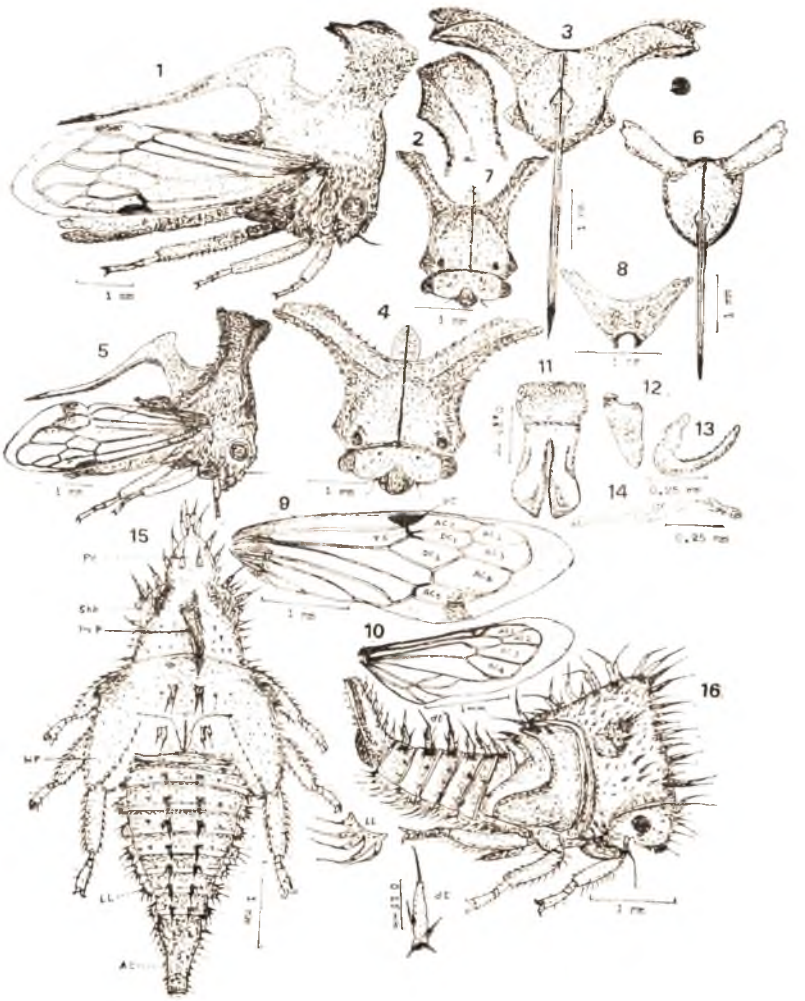
process broadly based, emerging behind the middie of disc, finely tuberculate at basal stem, pale ochraceously brown beyond stem, apex pitch black, at basal elevation inwardly angulate, then obliquely and sinuately continued, apical half gradually acuminate to tip which almost touches the apical limbus beyond the tip of abdomen: lateral areas of sternum cretaceously sericeous; scutellum brown, punctate with long pilosity, nearly twice as wide as long, tip slightly rising with a U-shaped emargination, apices acute. Tegmina 3.3 times longer than wide, dark reddish brown, apical area nearly hyaline, veins brown, a prominent dark brown patch at posterior angle of inner margin, apical limbus moderately broad tip acutely rounded, base coriaceous and punctate, pterostigma black, about four times as long as wide, first apical six times longer than wide, first discoidal cell slightly shorter and narrower than second discoidal; veins bordering second and third apical cells slightly curved; hind wings with four apical cells. Legs black upto apices of femora, apical region of femora, tibiae and tarsi light brown.

Measurements: Length from frontal margins to tips of tegmina 6.5 mm, to tip of posterior process 5.5 mm, width across tips of suprahumeral horns 4.6 mm, st humeral angles 2.25 mm, at eyes 2.0 mm.

Male: General coloration as in female, but devoid of the cretaceously sericeous line on each side behind the suprahumeral horns; metopidium broader than high; suprahumeral horns broad, strongly tuberculate, three times longer than the space between their bases, directed obliquely upwards; width across tips of suprahumeral horns much less than that of female; apices of suprahumerals slightly widened and obliquely concavely excavate; posterior process obliquely elevated at base, slightly ampliate its apex extending well behind the tip of abdomen. Tegmina thrice as long as wide, first apical cell five times longer than wide, first discoidal cell shorter than second, the latter twice as wide as the former, a chocolate brown patch at posterior angle of inner margin and extending into fifth apical cell; hind wings with four apical cells; genitalia dark brown, parameres halberd-shaped, light brown, aedeagus U-shaped, its inner margin weakly serrate, ventral plate deeply cleft to the base, its tip slightly expanded and rounded, lateral valves wedge-shaped, their processes short and nodular.

Measurgments: Length from frontal margin to tips of tegmina 4.5 mm, to tip of posterior process 4.0 mm; width across tips of suprahumeral horns 2.6 mm, at humeral angles 1.7 mm, at eyes 1.5 mm.

Fifth instar immature: 4.3-5.0 mm long. General coloration yellowish green in life, fading to greyish brown in cabinet specimens. Body nearly triangular in cross section, laterally compressed and densely bristled; head about 2.75 times as wide as long, nearly vertical, upper margin of vertex sinuate with a row of tuberculated spines, rostral tip reaching third abdominal segment, cranial tubercles obsolete, but represented by a pair of stout tuberculated spines; eyes moderately large, bordered by short spines, ocelli inconspicuous, nearer to eyes than to each other and located above the centro-ocular line; prothorax larger than pterothorax; pronotum higher than wide, rising vertically



Anchon ulniforme Buckton:

Fig. 1. Female, lateral aspect; 2—Female, dorso-lateral view of the apex of horn; 3—Female, dorsal aspect of pronotum; 4—Female, frontal view; 5—Male, lateral aspect; 6—Male dorsal aspect of pronotum; 7—Male, frontal view; 8—Male, scutellum; 9—Male, tegmina; 10—Male, hind wing; 11—Ventral plate; 12—Lateral valve; 13—Aedeagus; 14—Paramere; 15—Fifth nymphal instar, dorsal aspect; 16—Fifth nymphal instar, lateral aspect; Ac1—Ac5, apical cells; At, anal tube; dc1—dc2, discoidal cells; dt, dorsal tubercle; LL, lateral lamella; Pt, pronotal crest; Prp, pronotal posterior process; pt, pterostigma; rs, radial sector; Shb, suprahumeral bud; WP, wing pad.

from frontal margin and curving into a broadly rounded, slightly laterally compressed crest, terminating in a cluster of long tuberculated spines, then descending and produced backwards into a simple acute process; pronotal tubrculated spines prominent, each tubercle terminating in a single or double spine, directed forward; pronotal posterior process prominent, extending as far behind as middle of mesonotum, suprahumeral buds viewed in lateral aspect large, oval, projecting laterad and forward, fringed with a cluster of tuberculated spines; mesonotum twice as wide as long, with a pair of stout dorsal tubercles, each tipped with two backwardly directed tuberculate spines; mesonotal process overlapping metanotum; metanotum narrow, about half as long as mesonotum. With dorsal tubercles similar to those of mesonotum; tegminal wing pads 1.3 mm long, greyish brown, their costal angles distinct, fringed with a row of short tuberculated spines besides small spines scattered all over; hind wing-pads shorter, partially overlapped by tegminal wing-pads. Legs uniformly brown, fringed with short tuberculated spines, tibiae moderately flat. Abdomen about 1.5 times as long as thorax, attaining its maximum width at the level of fourth abdominal segment; abdominal segments 3-7 each with ferruginous dorsal tubercles directed upwards, each tubercle about 0.25 mm long, tipped with a long, slender spine besides two subspines at the basal half; lateral lamellae of second abdominal segment shorter than the succeeding ones, those of abdominal segments 3-7 more or less uniform, flat, crescentic, each bearing five or six tuberculated spines curving backward; anal tube stout, a little more than one-fifth of the total body length, fringed with rows of tuberculate spines, with genital rudiments distinctly visible beneath.

Material examined: Numerous females, males and immatures on *Lablab purpureus* (L.), Trivandrum, during July, 1980.

Remarks: Distant (1908), while describing the generic diagnosis of *Anchon* Buckton, has referred to the presence of only three apical areas in the hind wings; this condition may perhaps be true of the type of this genus, *Anchon* (= *Centrotus) nodicornis*, described by Germar (1835) from Cape of Good Hope and redescribed by Capener (1972), although no mention has been made about the hind wings by both these authors. Capener (1968) has stated that the number of apical cells in the hind wings is remarkably constant in all the species of all tribes included in the Subfamily Centrotinae. The number of apical cells in the hind wings has formed an important criterion to separate the tribes, Leptocentrini and Centrotini, the former having four apical cells and the latter, three; on this basis, the genus *Anchon* is allocated to the tribe Centrotini. However, it has been observed by Ananthasubramanian and Ananthakrishnan (1975) that all the specimens of *Anchon echinatum* Dist. collected from South India revealed four apical cells in the hind wings, and the same has been noticed presently in *ulniforme* as well. That the present situation is not an intraspecific variation is obvious as revealed from the examination of a long series of specimens belonging to the same population.

Biological notes: The eggs are laid into the fleshy succulent stem of the host plant, *Lablab purpureus*, cut deep with the help of the powerful ovipositor of the female soon after the first showers

of monsoon in June; the eggs are arranged in regular rows inside the oviposition puncture which does not heal up completely and leaves a crescentic or boat-shaped slit or scar. The eggs are cigar-shaped and measure, on an average, 0.8 mm long and 0.25 mm wide. They hatch out in 4-7 days into tiny light brown or greenish immatures which are gregarious and feed on the plant sap. The coloration of the immatures or nymphs blends with their background, making them inconspicuous. There are five instars as in other species of Membracidae. The moulted skin is very perfect with regard to the chaetotaxy and easily referable to the species to which it belongs. The time taken for passing through the nymphal stages varies from 18 to 25 days. One generation is completed in about four weeks. The insect completes three or four generations on the same host plant by the middle of September whereupon the adults migrate to other host plants of the same species or very often attack fresh host species such as *Vigna catiang*, *Phaseolus mungo* and *Canavelia gladiata*. It is noteworthy that this membracid species attacks only the plants belonging to the natural order Fabaceae. By the end of December, they almost completely disappear till the commencement of the next South West monsoon. Although the damage due to the suction of plant sap is rather insignificant and does not appear to be considerable, the deep egg-slits of the female prove detrimental to the tender twiners which consequently dry up or snap easily. The gregarious nymphs, as in the case of most other membracid species, secrete "honey dew" which is eagerly sought after by ants and some flies like *Silba* sp. The common camponotine ant that is usually associated with the nymphs of this membracid species is *Plagiolepes* sp. Often, the long trails of this ant betray the hiding places of the membracid nymphs. In the course of the present study, it was observed that the eggs of this membracid are parasitized by an undetermined species of trichogrammatid and an unidentified eulophid species.

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FOUR NEW SPECIES OF ERIOPHYID MITES (ACARINA: ERIOPHYOIDEA) FROM WEST BENGAL, INDIA

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Four new species viz., *Cymoptus bengalensis* infesting *Mallotus repandus* Muell., *Oxycenus diospyrosis* infesting *Diospyros melanoxylon* Roxb., *Tetra limonis* infesting *Limonia* sp. and *Tetra aegleis* infesting *Aegle mormelose* Corr. are described. Distribution, relationship and host plant associations of these new species are also discussed.

(Key words: Acarina, eriophyids, taxonomy, morphology, new species, India)

This paper contains descriptions of 4 new species viz., *Cymoptus bengalensis*, *Oxycenus diospyrosis*, *Tetra limonis* and *Tetra aegleis*. The genus *Cymoptus* Keifer (1946) was so far monotypic.

1. Cymoptus bengalensis, sp. nov. (Fig. 1)

Female: Body 133—168 long, 34—50 wide, wormlike, whitish in colour. Rostrum 18—23 long, curved down diagonally; antapical seta 6—8 long. Shield subtriangular with short anterior lobe, 22—27 long and 27—35 wide; shield design represents only a number of very close longitudinal lines (26—30); median line straight and complete; admedian lines parallel to median line; submedian lines 23—27, almost parallel to each other; last few submedian lines are discontinuous. Dorsal tubercles almost on rear shield margin, 9—16 apart; dorsal shield setae 19—24 long, directed up and laterad. Forelegs 33—36 long from trochanter base; femur 7—9 long with a seta 10—14 long; patella 3—5 long with a seta 22—38 long; tibia 4—8 long without seta; tarsus 6—9 long with two setae, each 16—23 long; claw 4—6 long, without knob; feather-claw 5-rayed. Hindlegs 27—33 long from trochanter base; femur 7—9 long with a seta 9—12 long; patella 3—6 long with a seta 10—14 long; tibia 4—6 long; tarsus 4—8 long with a shorter seta of 14—18 long and a longer seta of 18—27 long; claw 7—9 long. Anterior coxae contiguous with a distinct median suture; first coxal tubercles far ahead of the level of anterior coxal approximation; second coxal tubercles much ahead of the transverse line across third coxal tubercles. Both the coxae ornamented with distinct diagonal lines.

Abdomen with about 75—82 tergites and sternites; both tergites and sternites are microtuberculated; microtubercles are rounded and present within the rings on tergites and on ring margin of sternites except a few telosomal rings which are microstriated. Lateral seta 18—27 long, on about sternite 11; first ventral seta 42—54 long on about sternite 25; second ventral seta 31—45 long on about sternite 44; third ventral seta 13—18

All measurements are expressed in μm.

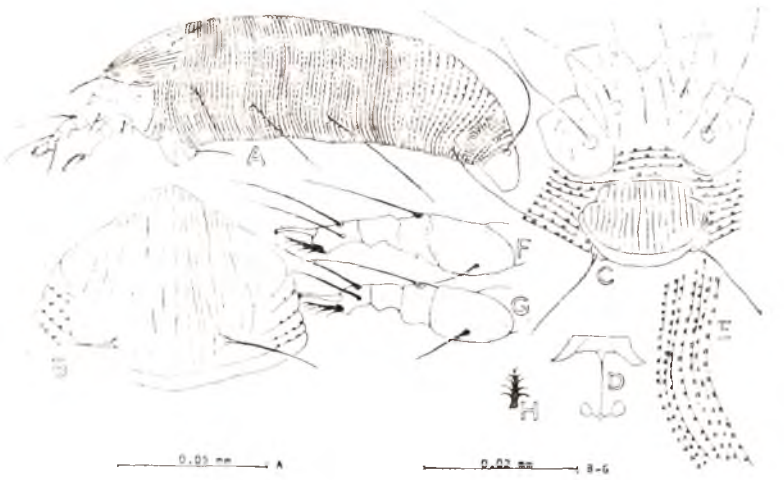

Fig. 1. *Cymoptus bengalensis* sp. nov.
Abbreviations used in Figs. 1–4: A—Lateral view of mites; B—Anterior dorsum of mite; C—Coxae with female genitalia; D—Internal genitalia (apodemes); E—Side skin structure; F—Fore leg; G—Second leg; H—Featherclaw (empodium); I—Male genitalia or Male genitalia with coxae.

long, on about sternite 72; caudal seta 52—76 long; accessory seta missing. Female genitalia 16—21 wide and 12—15 long; genital coverflap with about 15—18 longitudinal scorings; genital seta 9—14 long.

Male: Unknown.

Holotype: ♀, on slide (No. 422/141/81), INDIA: WEST BENGAL: Hooghly, Khalisani, 13.xi.1981, *ex Mallotus repandus* Muell., (Euphorbiaceae), coll. B. Ghosh. **Paratypes**: 10 ♀♀, on the holotypic slide and 27 ♀♀, on 2 slides (Nos. 423—424/141/81), collection data as in the holotype.

Relationship with the host plant: These mites were found to infest the ventral surface of leaves and occur as leaf vagrants. Due to infestatson, no damage symptom was noticed.

Cymoptus bengalensis sp. nov. differs from the only known species *C. spiniventris* Keifer (1946) under the genus *Cymoptus* by its 5—rayed featherclaw, nature of tergites, sternites, genital coverflap and shield design.

2. Oxycenus diospyrosis, sp. nov. (Fig. 2)

Female: Body 106—160 long, 42—71 wide, fusiform, dark brownish in colour. Rostrum 22—27 long, projecting down with antapical seta 7—9 long. Shield subtriangular, with distinct anterior lobe, 30—41 long and 42—56 wide; shield design simple with only median and admedian lines; median line present only on posterior 0.66 part only; admedian lines sinuate, arising from either side of anterior shield lobe, run backwards and ultimately meet rear shield margin. Dorsal tubercles placed on rear shield margin, 28—33 apart from each other; dorsal shield seta 10—13 long directing caudad. Forelegs 29—35 long from trochanter base; femur 7—11 long with a seta 7—12 long; patella 3—5 long with a seta 16—21 long; tibia 4—6 long

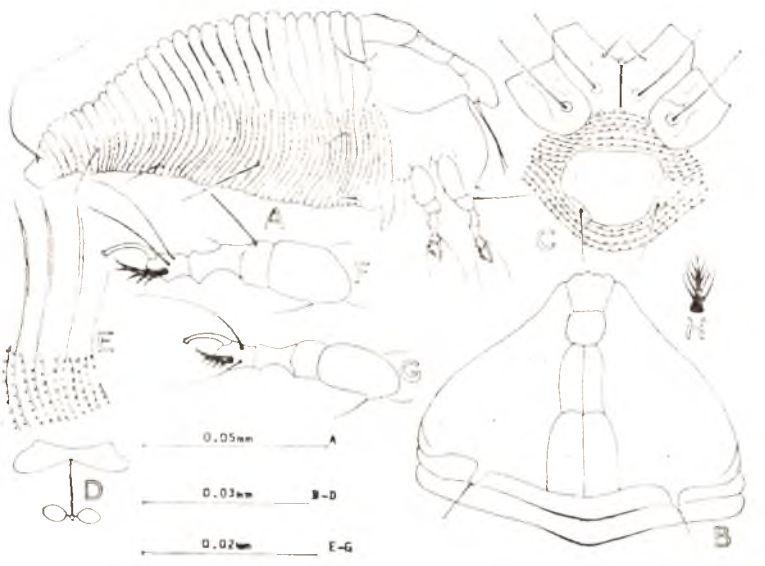

Fig. 2. Oxycenus diospyrosis sp. nov.

with a sete 4—7 long on basal 0.33 part tarsus 6—8 long with two setae each 21—24 long; featherclaw 5—rayed: claw 6—8 long, without knob. Hindlegs 26—33 long from trochanter base: patella without seta and other characters as in foreleg. Anterior coxae contiguous, with a distinct median suture: first coxal tubercles at the level of anterior coxal approximation: second coxal tubercles near the third coxal tubercles: coxae almost without any ornamentation except a few faint longitudinal lines.

Abdomen with about 25—30 tergites and 46—51 sternites; abdominal thanosome with a dorsal depression just ahead of telosome. Microtubercles present only on sternites as elongated bead like structures. Lateral seta 13—18 long, on about sternite 8; first ventral seta 20—26 long, on about sternite 21: second ventral seta 9—12 long, on about sternite 33, third ventral seta 13—20 long, on about sternite 44; caudal seta 31—45 long; accessory seta absent. Genitalia 16—22 wide, 12—28 long; genital coverflap with longitudinal scorings; genital seta 7—11 long.

Male: Unknown.

Holotype: ♀, on slide (No. 464/154/81) INDIA, WEST BENGAL, Bankura, Dubrakone, 15.xii.1981 *ex Diospyros malanoxylon* Roxb., (Ebenaceae), coll. B. Ghosh. **Paratype**: 3 ♀♀, on the holotypic slide and 18 ♀♀, on 3 slides (No. 465—467/154/81), collection data as in the holotype and 6 ♀♀, on 1 slide (No. 389/135/82), BIHAR: Santhalpargana, Massanjore, 15.v.1982, *ex Diospyros melaxylon* (Ebenaceae), coll. A. Das.

Relationship with the host plant: The mites inhabit the ventral surface of leaves as simple leaf vagrants without causing any injury to their host.

So far only 2 species of the genus *Oxycenus* Keifer (1961) viz, *O. maxwelli* (Keifer, 1939) and *O. niloticus* Zaher and Abou Awad (1979) are known. *Oxycenus diospyrosis* sp. nov. differs from the above two species by its 5—rayed

featherclaw, shield design besides other characters.

3. Tetra limonis, sp. nov. (Fig. 3)

Female: Body 92—137 long, 41—56 wide, dorsoventrally flattened, fusiform, brown in colour. Rostrum 18—25 long, projecting diagonally down, with antapical seta 5—7 long. Shield subtriangular, 28—35 long, 44—53 wide, with prominent anterior lobe over rostrum; shield design represents a network of cells; median line complete, faint on anterior half and prominent on rear half; admedian lines sinuate, joined with the median line posteriorly by an oblique line ahead of rear margin; submedian lines sinuate arising from anterolateral margin, bifurcate after a short distance, the inner fork joined with the admedian line by three oblique lines forming three cells; the outer forks run backwards divergently upto 0.5 part of the shield, then become convergent and meet the rear shield margin after receiving a cross line from the inner fork. Dorsal tubercles placed on rear margin, 24—32 apart from each other; dorsal setae 4—7 long, directed caudad. Forelegs 24—29 long from trochanter base; femur 5—9 long; with a seta 7—13 long; patella 3—4 long; with seta 14—19 long; tibia 3—5 long with seta 4—6 long on basal 0.33 part; tarsus 4—5 long with setae 13—17 long; claw 4—5 long; featherclaw 5—rayed. Hindlegs 21—26 long from trochanter base; femur 5—7 long; patella 3—4 long with seta 5—8 long; tibia 3—4 long without seta; tarsus 4—5 long with seta 12—17 long; claw 4—5 long; other characters as in the foreleg. Anterior coxae contiguous with a distinct median suture; both the coxae ornamented with irregular dotted lines. First coxal tubercles at the level of anterior coxal approximation; second coxal tubercles very near the level of third coxal tubercles.

Abdomen with about 25—31 smooth, moderately broad tergites and about 48—54 microtuberculate sternites; dorsal

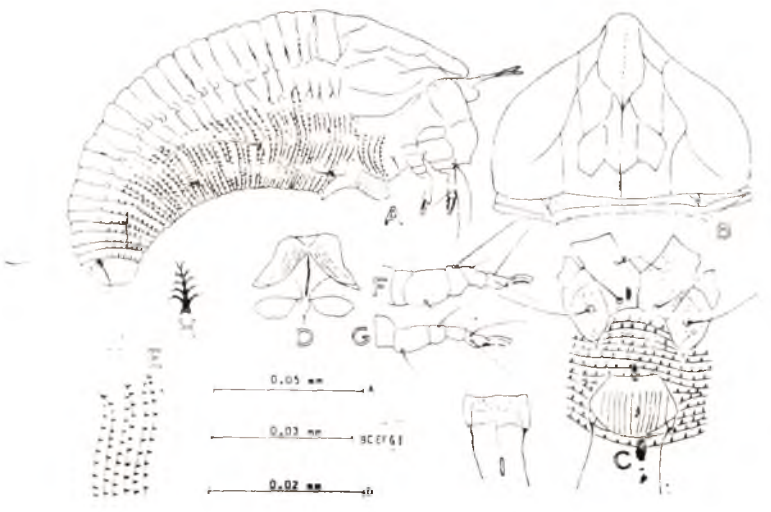

Fig. 3. *Tetra limonis* sp. nov.

thanosome with a wide trough havinlg distinct lateral ridge; first tergite much wide, touching the rear margin of second tergite and with striations. Microtubercles present only on sternites as elliptical bodies. Lateral seta 14—22 long, on about sternite 11; first ventral seta 31—38 long, on about sternite 21; second ventral seta 5—8 long, on about sternite 35; third ventral seta 15—22 long, on about sternite 47; caudal seta 34—61 long; accessory seta 4—6 long. Female ganitalia 13—18 wide; 10—14 long; coverflap with about 12 longitudinal ribs; genital seta 10—15 long.

Male: Body 101—135 long, 42—49 wide. Genitalia 11—13 wide: genital seta 12—14 long.

Holotype: ♀, on slide (No. 490/162/80), INDIA: WEST BENGAL: Hooghly, Khalisani, 10 vii.1980, *ex Limonia* sp. (Rubiaceae), coll. B. Ghosh, **paratypes**: 11 ♀♀ and 3 ♂♂ on the holotypic slide and 39 ♀♀ on 3 slides (Nos. 490—493/162/80), collection data as in the holotype.

Relationship with the host plant: These mites inhabit the ventral surface of eaves as sinple leaf vegrants without causing any injury.

The 5-rayed featherclaw of the two new species of the genus *Tetra*, viz., *T. aegleis* and *T. limonis* brings them nearer to *T. kingi* Styer (1975), *T. lanneansis* Chakrabarti *et al.* (1981), *T. rhamni* Roivainen (1951) and *T. rhodesiae* Keifer (1963). But from all these species, the present two new species differ by their shield design in addition to other characters in detail. The present two new species differ from each other by coxal ornamentation, microstriated first tergite (in *limonis* sp. nov.) in addition to detail shield design.

4. Tetra aegleis, sp. nov. (Fig. 4)

Female: Body 105—180 long, 43—58 wide, fusiform, brownish in colour. Rostrum 23—29 long, curved down or some times projecting perpendicular down; antapical seta 6—9 long. Shield subtriangular, 30—35 long, 44—53 wide; shield design represents a network; median line complete and distinct; admedian lines sinuate, arising from lateral margin of anterior lobe, run backwards first divergently upto base of anterior lobe, then become shortly convergent and bifurcate

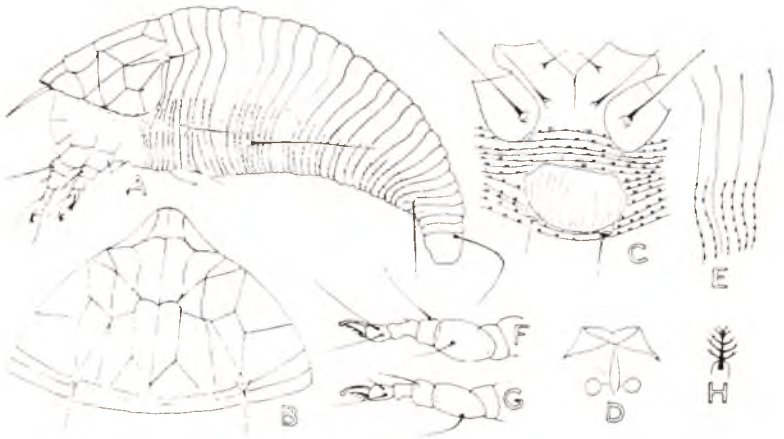

Fig. 4. *Tetra aegleis* sp. nov.

on 0.2 part of posterior shield margin; the outer fork meets the rear shield margin obliquely and the inner fork meets the median line somewhat ahead of rear margin; median line connected with the admedians on anterior 0.2 and 0.5 part of shield by two cross lines which further extend forward to meet the lateral shield margin: submedian lines two, both sinuate and complete and inter-connected with each other by oblique lines forming unequal cells (3—4) in between. Dorsal tubercles on rear shield margin, 27—32 apart and setae directing caudad and 8—11 long. Forelegs 26—31 long from the trochanter base; femur 6—8 long with a seta 9—3 long: patella 3—4 long with a seta 18—22 long: tibia 5 long with a seta on basal 0.33, 5—6 long; tarsus 4—5 long with setae 17—22 long; claw 4—6 long with knobbed apex; featherclaw 5-rayed. Hindlegs 24—27 long from trochanter base: patella with a seta 6—8 long: tarsus with a long seta 18—20 long and with a short one 10—15 long; other characters as in the forelegs. Anterior coxae contiguous with a distinct median suture; first coxal tubercles at the level of anterior coxal approximation: second coxal tubercles slightly ahead of the level of third coxal tubercles; both the coxae almost without any ornamentation.

Abdomen with about 26 broad tergites and about 49—55 narrow sternites dorsal thanosome with a broad trough; microtubercles distinctly present as bead like structures on ring margin of sternites and faint impression of microtubercles present on tergites. Lateral seta 20—30 long, on about sternite 12; first ventral seta 29—40 long, on about sternite 20; second ventral seta 8—11 long, on about sternite 33; third ventral seta 15—21 long, on about sternite 47; caudal seta 40—68 long; accessory seta 4—5 long. Genitalia 13—19 wide, 10—15 long: genital coverflap with about 12—15 longitudinal scorings; genital seta 17—23 long.

Male: Body 105—139 long, 43—47 wide. Genitalia 11—13 wide; genital seta 13—15 long.

Holotype: ♀, on slide (No. 487/163/81), INDIA: WEST BENGAL, Midnapore, Fakirgang, 23.ii.1981, *ex. Aegle mormelose* Corr, (Rutaceae), coll. B. Ghosh. **Paratypes**: 10 ♀♀ and 4 ♂♂, on the holotypic slide and 27 ♀♀ on 2 slides (Nos. 488—489 163/81), West Bengal Bankura, Bishunpur, on the same plant coll. B. Ghosh.

Relationship with the host plant: These mites infest the ventral surface of new leaves without causing noticeable injury to their host plant.

The type material is deposited at present in the collection of Biosystematics Research Unit, Department of Zoology, University of Kalyani. Number of paratypes presented on approximate calculation.

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